



A TAXONOMIC REVISION OF THE
AUSTRALIAN PULVINARIINI
(HEMIPTERA: COCCOIDEA: COCCIDAE)

THESIS SUBMITTED TO
THE AUSTRALIAN NATIONAL UNIVERSITY FOR
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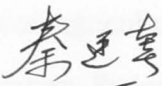
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DECLARATION

This thesis does not contain any material which has been previously submitted for the award of any degree or diploma at any university. This is my own work and the assistance received from institutions and individuals has been acknowledged.


(Qin Tingkui)
Ting Kui Qin

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ABSTRACT

A taxonomic revision of the Australian Pulvinariini is presented and thirteen species are described and illustrated in detail. The species are: *Pulvinaria decorata* Borchsenius, *P. dodonaeae* Maskell, *P. elongata* Newstead, *P. flavicans* Maskell, *P. floccifera* (Westwood), *P. hydrangeae* Steinweden, *P. maskelli* Olliff, *P. mesembryanthemi* (Vallot), *P. polygonata* Cockerell, *P. psidii* Maskell, *P. salicorniae* Froggatt, *P. thompsoni* Maskell and *P. sp. n.* Ten new synonyms are proposed (junior synonym first): *P. greeni* Froggatt = *P. dodonaeae*; *P. tecta* Maskell and *P. contexta* Froggatt = *P. flavicans*; *P. theae* Froggatt = *P. floccifera*; *P. maskelli* var. *spinosior* Maskell, *P. maskelli* var. *novemarticulata* Green, *P. nuytsiae* Maskell and *P. newmani* Froggatt = *P. maskelli*; *P. darwiniensis* Froggatt = *P. psidii*; and *P. paradelpha* Cockerell & Lidgett = *P. thompsoni*. A key to all Australian species based on the adult females is provided. A diagnosis and distribution and host-plant data are presented for all species.

The revision introduces some new and unique features for the Pulvinariini. These are submarginal chambered ducts, spiracular sclerotisation, the unusual multilocular pores in *P. flavicans*, the large-based marginal setae, the reticulated anal plates and the special structure of microducts on the dorsum of *P. maskelli*. These characters raise questions about the taxonomic status of some Australian species.

A brief summary of the study of Pulvinariini is presented chronologically for the world fauna, and the taxonomy, phylogeny and distribution of this group of insects are discussed. All Australian pulvinariine species should be retained in *Pulvinaria* until a phylogenetic study of the world fauna has been undertaken.

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CHAPTER 1

INTRODUCTION

1. 1. The genus *Pulvinaria* Targioni-Tozzetti and the tribe Pulvinariini Ashmead

The genus *Pulvinaria* was established by Targioni-Tozzetti in 1866 based on characters of the adult female of *Coccus vitis* Linnaeus which produced 'floccose material' (the ovisac of modern authors). *Pulvinaria* used to include all soft scales (family Coccidae) in which the adult female produced an ovisac, however, the group has been broken up into many genera (see Chapter 2 for details).

The tribe Pulvinariini was established by Ashmead (1891) to include two genera, *Lictensia* [sic] Signoret and *Pulvinaria*. However, many other genera, closely related to the genus *Pulvinaria*, have been described without reference to the tribal system and were not specifically included in the tribe Pulvinariini until the revisionary work of Borchsenius (1957). Borchsenius (1957), who studied the Palaearctic fauna, redefined the tribe and included 11 genera. *Lichtensia* is no longer included the tribe (Borchsenius, 1957; Kosztarab & Kozár, 1988).

In the present review, Pulvinariini refers to all soft scales in which the adult female produces an ovisac and the colloquial name 'cottony soft scales' is used here for the Pulvinariini, although other names, such as 'cushion bearers' and 'cottony scales', have been used for this group (Borchsenius, 1957; Williams & Kosztarab, 1972; Gill, 1988).

Most coccid studies, including the present work, are confined to the adult females. The reason for this is that adult females are commonly encountered and collected because they are conspicuous, large, and live for a comparatively long time. Even if they die, the dead bodies remain attached to their host plants in a condition suitable for morphological study; in the contrast, the adult males are difficult to find and rarely collected because they are inconspicuous, small and ephemeral, usually living from a few hours to a day (Boratynski & Davies, 1971; Miller & Kosztarab, 1979).

1. 2. Australian species of *Pulvinariini*

In Australia, there are names of 22 species and three subspecies available in literature. All species were placed in *Pulvinaria* by the original authors and have not been studied for more than 60 years (see Chapter 2 for a review of the Australian literature). The available descriptions are inadequate and therefore, the species in Australia are taxonomically unrecognisable, although sometimes they can be tentatively identified by their host-plant associations.

After an initial examination of the literature and specimens it was apparent that: (1) some species occurring in Australia also occur elsewhere and may be cosmopolitan or at least widely dispersed, probably as a result of human activity; and (2) many species previously placed in the genus *Pulvinaria* have been transferred to other closely related genera, and so the nomenclature and taxonomic status of species in the *Pulvinariini* are very confused. It would be impossible to produce a taxonomic revision of the Australian species of *Pulvinariini* without studying closely related genera and without looking at non-Australian species. Therefore, the history of the study of *Pulvinariini* is summarised in Chapter 2.

1. 3. Economic Importance

Many species of *Pulvinaria* are polyphagous and some of them have been reported as important pests. *Pulvinaria delottoi* Gill and *P. mesembryanthemi* (Vallot) are serious pests of iceplant in California (Gill, 1979, 1988). *Pulvinaria psidii* Maskell is a pest of ornamentals, particularly *Ficus* species in Florida (Hamon & Williams, 1984). There have been several outbreaks of *P. iceryi* (Signoret) on sugarcane in Reunion and Mauritius (see Williams, 1982).

In Australia, *P. maskelli* Olliff can seriously damage salt bush (Olliff, 1891, 1892). Briese (1982) estimated that a mean of 17% of branches of *Atriplex vesicaria* were killed by *P. maskelli* in southwestern New South Wales in 1973 and that attendance by ants contributed to the damage potential of the scales. *Pulvinaria polygonata* Cockerell infests citrus species in Queensland (Summerville, 1934) and its largest

populations are found on four to six year old trees. Infestations of the scale affect the size of the fruit and are often accompanied by sooty moulds which increase the damage.

The identification of pest species of soft scales is hampered in Australia by lack of detailed taxonomic treatment of the group.

1. 4. Aims of this study

The objectives of the present study of the Australian Pulvinariini are as follows:

1. to examine the taxonomic status of every available name in Australia.
2. to describe or redescribe and produce detailed illustrations of the adult females of all valid, previously named species and any new species, and
3. to provide a key to all Australian species based on the adult females.

The thesis is structured as follows: Chapter 2 reviews the world literature on the tribe Pulvinariini; Chapter 3 discusses the material studied and explains the methods used; Chapter 4 describes the general morphological characters of the adult females; Chapter 5 provides a key to the Australian species based on the adult females and describes each species; and Chapter 6 discusses the Australian Pulvinariini in relation to the taxonomy, phylogeny and distribution of the world fauna.

CHAPTER 2

HISTORY OF THE STUDY OF THE TRIBE PULVINARIINI ASHMEAD WITH SPECIAL REFERENCE TO AUSTRALIA

2. 1. Introduction

More than 200 species of Pulvinariini have been described from all over the world and the primary literature is scattered through five continents. The following review is chronological and includes most of the literature related to the cottony soft scales. The emphasis is on study of the adult female but studies of the immature stages, the male puparia and adult males are discussed. The Australian fauna is discussed separately in the last section.

2. 2. Study of the adult female

After erecting *Pulvinaria* in 1866, Targioni-Tozzetti (1869) included this genus in Section B, Pulvinati, of his tribe 'Lecanites' (see Morrison & Morrison, 1966). Signoret (1873) seems to have been the first^{subsequent} author to have acknowledged the genus and his study included 18 species of *Pulvinaria*, some of which were transferred from *Coccus* and '*Lecanium*' (now an invalid name; Opinion 1303, 1985).

Following Signoret, only a few species were added to *Pulvinaria* from various parts of the world (Löw 1883; Maskell, 1889, 1891; Olliff, 1891, 1892; Newstead, 1892) until Cockerell (1893) began a series of papers describing more than 20 pulvinariine species, including attempts to break up *Pulvinaria* into several subgenera which were later raised to generic level. Cockerell (1899b) erected the following generic names: *Protopulvinaria*, *Takahashia*, *Philephedra* and *Lagosinia*. Hempel (1899) in Brazil also separated another genus, *Pulvinella*, from *Pulvinaria* and recognised one further genus, *Tectopulvinaria* (Hempel, 1900).

By 1903, Fernald was able to include 67 species from five genera of cottony soft scales in her catalogue of the world species of Coccidae (Coccoidea of modern authors).

Two further genera of Pulvinariini, *Allopulvinaria* and *Pendularia*, were established by Brain (1920) and Fonseca (1927), respectively.

Steinweden (1929) precisely redefined the genus *Pulvinaria* based on morphological characters of the adult females and first instar nymphs. His work is considered to be the beginning of a modern classification of the family Coccidae on a world-wide basis (Williams & Kosztarab, 1972). Definitions of *Protopulvinaria*, *Philephedra* and *Takahashia* were also included in Steinweden's (1929) work. A new genus, *Phyllostroma*, was added to Pulvinariini by Sulc (1942). In 1946, Steinweden reviewed 13 species of North American cottony soft scales and placed all of them in the genus *Pulvinaria*.

Borchsenius split seven (not eight, Morrison & Morrison, 1966, p. 169) genera from *Pulvinaria*, naming them *Acanthopulvinaria*, *Anapulvinaria*, *Chloropulvinaria*, *Rhizopulvinaria* (Borchsenius, 1952), *Eupulvinaria*, *Pulvinariella* and *Pulvinarisca* (Borchsenius, 1953). Later, Borchsenius (1957) reviewed 120 pulvinariine species from the world fauna, recognised 62 Palearctic species in 11 genera, and indicated that many species originally placed in *Pulvinaria* should be transferred to other related genera. The definition of the Pulvinariini provided by Borchsenius has been accepted by many authors (Canard, 1965, 1965b; Danzig, 1980; Tereznikova, 1981; Young, 1982; Nakahara & Gill, 1985; Kosztarab & Kozár, 1988). Nevertheless, many of Borchsenius' generic concepts have not been accepted by all coccidologists, especially American authors (e.g. Williams & Kosztarab, 1972; Hamon & Williams, 1984; Gill, 1988).

Many regional faunas of Pulvinariini have been well reviewed and are listed as follows: in Asia: Japan (Takahashi, 1955, 1956; Kanda, 1960), Far East USSR (Danzig, 1980), China (Wang, 1982; Young, 1982), Taiwan (Tao, Wong & Chang, 1983); in North America: Virginia (Williams & Kosztarab, 1972), Florida (Hamon & Williams, 1984), North America (Nakahara & Gill, 1985), California (Gill, 1988); in South America: Brazil (Fonseca, 1972, 1973), in Europe: Georgia (Hadzibejli, 1955; Khadzhibeyli, 1978), Ukraine (Tereznikova, 1981), France (Canard, 1965), Hungary (Kosztarab & Kozár, 1978), Central Europe (Kosztarab & Kozár, 1988); in Africa:

Ethiopian region (Hodgson, 1967, 1968), Egypt (Ezzat & Hussein, 1969), South Africa (De Lotto, 1979).

From these revisionary works, some new genera of Pulvinariini have been described based on characters of the adult females. They include: *Neopulvinaria* (Hadzibejli, 1955), *Leptopulvinaria* (Kanda, 1960), *Macropulvinaria* (Hodgson, 1968), *Anopulvinaria* (Fonseca, 1972), *Mesembryna* (De Lotto, 1979), *Megapulvinaria* (Young, 1982), *Saccharipulvinaria* (Tao, Wong & Chang, 1983) and *Metapulvinaria* (Nakahara & Gill, 1985).

Apart from all the above, authors who have described or redescribed at least one species or subspecies of cottony soft scale are listed chronologically as follows (authors who described the Australian species are included in 'Study of the Pulvinariini in Australia' and not listed below):

Newstead (1894, 1908, 1917, 1920), Green (1896, 1904, 1907, 1908, 1909, 1915), Cockerell (1893a, 1893b, 1894, 1895, 1896, 1896a, 1896b, 1896c, 1898, 1898a, 1899a, 1905, 1905a); King & Cockerell (1898), Ehrhorn (1898, 1906), Leonardi (1898, 1911), Grandpre & Charmoy (1899), King (1899, 1900, 1901, 1901a), Lull (1899), Hunter (1900), Kuwana (1902, 1907, 1914), Nassanov (1908), Lindinger (1911), Hempel (1912, 1928), Robinson (1917), Bréthès (1918), Morrison (1920), Ferris (1921, 1950), Hall (1923, 1932), Joubert (1925), Ramakrishna Ayyar (1925), Bodenheimer (1926, 1943), Balachowsky (1929), Takahashi (1929, 1931, 1940), Shinji (1935), Rao (1939), Venkatraman (1941), Zimmerman (1948), McConnell (1949), Kanda (1950), Castel-Branco (1952), De Lotto (1954, 1964, 1965, 1966, 1967, 1967a, 1968, 1970), Mamet (1956, 1958), Phillips (1962), Richards (1964), Canard (1965a, 1965b, 1967, 1967a, 1968, 1968a, 1969), Danzig (1966, 1967, 1988), Bazarov (1971), Gill (1979), Williams (1982), and Avasthi & Shafee (1985).

2. 3. Study of the immature stages

Early authors (e.g. Signoret, 1873; Maskell, 1889, 1891, 1893, 1894, 1896, 1897; Olliff, 1892; see also Appendix A) usually described the immature stages if

available, especially first instar nymphs which are frequently found with the adult female. These early descriptions were mostly uninformative and were not used to separate species. In contrast, King (1906) described the first instar nymphs of six species of *Pulvinaria* and attempted to use them to help separate closely allied species. The characters that King and early authors described were proportions of appendages.

Steinweden (1929) used the morphological characters of first instar nymphs to help define *Pulvinaria*. Phillips (1962) described every stage of the species *P. vitis* (L.) and *P. innumerabilis* (Rathvau). The immature stages of *P. ellesmerensis* were described by Richards (1964). Canard (1965b) stated that the antennae, legs and spiracular setae were fairly uniform in the first instar nymphs of Pulvinariini, and he claimed that two characteristics of the first instar nymphs were stable, visible and easy to use in separating species: the length of the cluster of stylets and the shape of the crumena. Canard used these two characters to separate six related genera and later applied this method to separate five species of *Rhizopulvinaria* (Canard, 1968). Gill (1979) described in detail every stage of *P. dellotoi* Gill.

Howell (1984) reviewed recent studies on the utilization of immatures in the classification and phylogeny of scale insects, and noted that immature stages are important to classification and phylogeny. The first instar nymphs of Pulvinariini were not used in the classification.

2. 4. Study of the male puparia and adult males

2 .4. 1. Male puparium

The male puparium used to be called the 'male test' in early works (e.g. Maskell, 1893; Olliff, 1892) and has been termed a 'pupa' by other authors (e.g. Gill, 1988). Gill (1988) included colour photographs of male 'pupae' of several species in his study of Californian Coccidae. He discussed the puparium in the addendum and clearly distinguished the correct term 'puparium' from the colloquial term 'pupa'. The puparium is a cocoon-like structure inside which the process of change between the feeding immature and the nonfeeding adult male takes place.

Male puparia are much easier to obtain than adult males because the cocoon-like structure remains on plants after emergence of the adult. Early authors (see Appendix A) often included descriptions of male puparia when they described species, but did not use them to discriminate species. However, modern studies of Pulvinariini seem to have ignored the male puparia except for those of Canard (1967a, 1968, 1969) who described and illustrated the male puparia of *Rhizopulvinaria arenaria* Canard, *R. artemisiae* (Signoret) and *Eupulvinaria hydrangeae* (Steinweden). The male puparia may have some taxonomic value because the structures are different in these three species. The taxonomic value of male puparia requires evaluation, especially since they are easy to obtain.

2. 4. 2. Adult male

Early authors seem to have described the males available when they described new species (e.g. Löw, 1883; Maskell, 1891; Olliff, 1892; also see Appendix A), although male characters were not used to distinguish taxa. Recently, Giliomee (1967) studied males of the Coccidae including three species in two genera of Pulvinariini. He showed that male characters were useful for distinguishing groups at all taxonomic levels in the Coccidae and also showed that classifications based solely on males or solely on females were different. For example, the two genera, *Phyllostroma* and *Pulvinaria*, which Borchsenius (1957) included in the tribe Pulvinariini based on characters of the adult females, "... are widely different and have only a comparatively small number of characters (about 50) in common" (Giliomee, 1967, p. 146), on this basis of average similarity these were placed in different groups of approximately subfamilial rank by Giliomee (1967).

The males of many species of Pulvinariini have been described (see Appendix A), although early descriptions are inadequate.

2. 5. Study of the Pulvinariini in Australia

All Australian species of Pulvinariini were described in *Pulvinaria*. The first Australian *Pulvinaria* species, *P. flavicans*, was described by a New Zealander, Maskell

(1889). Subsequently, Maskell (1891, 1893, 1894, 1896, 1897) described a further five species and one subspecies from Australia based on specimens sent to him for identification. Maskell's descriptions usually included all the stages available, including the appearance of the unmounted insect and ovisac, details of the slide-mounted adult female, and brief consideration of first instar nymphs (his "larvae"), other immature stages, male puparia and adult males if available.

Olliff (1891, 1892) only described one species of Pulvinariini, *P. maskelli*. However, he managed to rear the insect, observed the life cycle, and described and illustrated the first instar nymph, second instar female, adult female and adult male. Cockerell & Lidgett (in Cockerell, 1899) contributed one species of *Pulvinaria* for Australia. Fuller (1899) described one subspecies from Western Australia and gave notes on another two species.

Froggatt (1910, 1915, 1921, 1921a, 1923) contributed to the study of Australian *Pulvinaria* more than any other author. The most comprehensive study of Pulvinariini in Australia so far is Froggatt's (1915) 'A descriptive catalogue of the scale insects ("Coccidae") of Australia', in which he included 14 species of *Pulvinaria*, of which six were new. This catalogue was republished in 1921. Unfortunately, Froggatt's descriptive techniques had not advanced over those in use in the 19th century. The descriptions of new and previously described species in Froggatt's work are wholly inadequate, mainly relying on the superficial appearance of the coccid on the host plant, and the only illustrations are also of the insects *in situ* on their hosts. Most of Froggatt's new species are synonyms, probably because he did not examine the cuticular structures of the insects in detail.

Following Froggatt's work, the only taxonomic reference to *Pulvinaria* in the Australian literature is by Brookes (1964) who mentions *P. hydrangeae*.

CHAPTER 3

MATERIAL AND METHODS

3. 1. Material and depositories

Almost all material studied was borrowed from the following museums and collections.

ANIC	Australian National Insect Collection, CSIRO, Canberra, Australian Capital Territory
BCRI	Biological and Chemical Research Institute, Rydalmere, New South Wales
BMNH	British Museum (Natural History), London, United Kingdom
DPI	Entomology Branch, Department of Primary Industries, Indooroopilly, Queensland
MVM	Museum of Victoria, Melbourne, Victoria
NZAC	New Zealand Arthropod Collection, Entomology Division, DSIR, Private Bag, Auckland, New Zealand
QM	Queensland Museum, South Brisbane, Queensland
SAM	South Australian Museum, Adelaide, South Australia
TDA	Tasmanian Department of Agriculture, Newtown, Tasmania
WADA	Western Australian Department of Agriculture, South Perth, Western Australia
WARI	Waite Agricultural Research Institute, Adelaide, South Australia

Some specimens were collected specifically for this study and have been deposited in ANIC. All the borrowed specimens have been returned to the appropriate lending institutions except that some type specimens borrowed from NZAC have been deposited in ANIC; details are specified in the relevant species descriptions.

Most coccoid specimens originally deposited in WARI have been transferred to ANIC. WARI formerly used 'Specimen Index Number' for coccoid specimens. These

numbers are included in the depositories listed in this thesis as, for example, '(ANIC; WARI No. 8/74)'.

If the specimen collection numbers and/or institutional depository numbers are available for the mounted or unmounted material, they are listed after the collector (for collection number, e. g. 'W.W. Froggatt No. 301') and/or after the depository (for institutional number, e. g. '(BMNH 1940, 180)').

3. 2. Slide-mounting

A large number of museum specimens were either dry or preserved in ethanol and it was necessary to mount them on microscope slides in order to examine the morphological characters. Some slide-mounted adult females were remounted. The mounting and remounting methods were those of Gullan (1981, 1984) with slight modification.

Dry specimens were soaked for 24 hours in a 1 : 1 mixture of the surfactant Decon 90 and 10% potassium hydroxide, rinsed in water and then soaked in water for 2-3 hours to allow re-inflation of the body.

Freshly collected specimens were fixed and preserved in lactic acid-ethanol. Specimens that required remounting were released from the old mount by soaking in xylene for several days until the coverslip could be removed. Then the insects were rehydrated by passing through a series of decreasing grades of ethanol from 100%, 95%, 90%, 80% and 70%, and then to water. The fresh, preserved and rehydrated specimens were soaked in cold 10% potassium hydroxide for 24 hours to macerate the body contents. Specimens were washed in water and the body contents were expressed.

All the specimens were stained overnight in a 1 : 1 mixture of acid alcohol and acid fuchsin solution. The composition of the acid alcohol was 2 parts of glacial acetic acid to 8 parts of 50% ethanol, and the acid fuchsin solution was composed of 0.5 gram of acid fuchsin stain, 25 ml of 10% hydrochloric acid and 300 ml of water. The stained specimens were dehydrated through a series of increasing ethanol concentrations from 70% to absolute, with 3 changes of at least 5 minutes each at each concentration. A

coverslip and weight (e.g. a glass vial) were applied to make the cuticle flat during dehydration. Dehydrated specimens were transferred to xylene with 3 changes in 30 minutes, and then mounted in Canada balsam in xylene. Each specimen was mounted on a separate slide under a 16 or 18 diameter circular coverslip. The slides were labelled, stored in flat trays and dried at room temperature.

A Kyowa Optical Model SDZ-PL binocular microscope was used for dissecting and slide mounting. A pair of optical scissors was used to cut the cuticle to allow the removal of the body contents. Either a small incision was made laterally on the prothorax or the specimen was cut three-quarters open along the dorsoventral line around the body.

3. 3. Scanning electron microscopy of pores and ducts

The structure of some pores and ducts were determined using a Scanning Electron Microscope (SEM). Gullan's (1979) method was employed for specimen preparation.

The first few steps of SEM specimen preparation were identical with those used for slide-mounting until staining. Then instead of staining the cuticle, the SEM specimens were placed in acid alcohol for 1 hour, dehydrated in ethanol and transferred to absolute amyl acetate via a graded ethanol-amyl acetate series. The insects were then placed into open dishes to allow them to air dry and glued onto specimen stubs using Pentel 'Roll'n Glue', coated with gold and examined under a Cambridge S 360 SEM. Photomicrographs were taken with Polaroid positive and negative film.

3. 4. Measurements

All measurements were made in either millimetres (mm) or microns (μm), as specified in the descriptions. Measurements of unmounted specimens were recorded as the range only and made using an ocular micrometer in a Kyowa dissecting microscope at magnifications of X10, 20 and 40. The insects usually become shrivelled in old and dry material and hence the length and width of dry specimens are likely to be less than those of slide-mounted specimens.

Measurements of slide-mounted specimens were made at magnifications of X40, 100, 400 and 1,000 using an eyepiece micrometer fitted in an Olympus compound microscope. If available, at least 10 specimens were measured for each species, with the actual number measured specified for each description. In order to cover the variation in maximum range, the measured specimens were selected from different host plants and localities, wherever possible. Structural variation was recorded as the range with the mean and standard deviation in parentheses if 10 or more specimens were measured, e.g. 20-300 (225±54) μm , except that setal length was recorded as the range only.

All measurements were taken at the greatest dimensions. However, the body width was always the width of the ventral surface even if the dorsal surface was sometimes much wider. The length of the ovisac was measured medially from the posterior end of the body to the posterior end of the ovisac, although the ovisac usually extends laterally to the anterior part of the female's body. The trochanter and femur of each leg were measured together because the trochanter is small and usually triangular and measurement of its median line would not be accurate. Some other authors (e.g. Williams, 1985) also have measured the trochanter and femur as a unit. The length of the anal cleft was measured from the posterior anal plate angle to the posterior apices of the body. Setal lengths included the basal ring. The length of the microduct on the venter included the inner filament. The width of the anal ring was measured for all specimens but the length could not be measured for some species due to the orientation of the anal ring.

3.5. Figures

The illustration of the adult female of each species represents a generalised individual based on all of the specimens studied. It was not possible to draw just from type specimens because most were overmature and the cuticle was heavily sclerotised and poorly cleared, so that certain characters could not be seen. Moreover, some species, e.g. *P. maskelli*, exhibit a range of variation for certain characters, so that no single specimen displays the complete range.

The outline of each figure was drawn using a Nikon Micropan Microprojector which projects an image of the slide-mounted specimen onto a vertical surface. The enlargements were drawn by observation under a Olympus compound microscope. Each figure consists of a central drawing of the insect with the dorsum on the left and the venter on the right surrounded by enlargements of certain taxonomic characters. The enlargements are not to the same scale in all species and are not in proportion to each other within one figure. The enlargement of each structure is referred to by the same letter in all drawings and the lettering system follows the order of citation of structures in the descriptions. The enlargement of the anal ring was not drawn for some species, because it was obscured by its orientation.

3. 6. Terminology

The morphological terminology is from that of Williams & Kosztarab (1972) with three exceptions. These are: anterolateral and posterolateral margins instead of cephalolateral and caudolateral margins for the anal plates; microducts on the dorsum rather than bilocular pores (the reasons are explained in chapter 4).

Some characters are described for Pulvinariini for the first time and these include the inner margin setae of the anal plates, the spiracular sclerotisation and the submarginal chambered ducts. These will be discussed in detail in chapter 4.

3. 7. Common names

The common names, if available, were taken from the most recent publications, and the sources are given in parentheses after the names. If no common name was available, one has been suggested for each species.

3. 8. Diagnoses

The diagnosis of each species includes the appearance of whole dry adult females and important taxonomic features of slide-mounted specimens.

The description of the appearance of each species was based on dry material in which the adult female had produced an ovisac. These diagnoses may help to identify the insects prior to slide-mounting. Furthermore, many cottony soft scales are not noticed until they produce an ovisac. For the species for which dry material was not available, appearance descriptions were quoted from the most recent works: *P. elongata* from Hamon & Williams (1984) and *P. floccifera* and *P. hydrangeae* from Gill (1988).

The diagnoses for slide-mounted specimens include the most distinctive attributes of species. These diagnoses were designed to allow recognition of all pulvinariine species in Australia. However, the diagnoses for most Australian species will also allow them to be distinguished from other world pulvinariini because the Australian species have some peculiar features.

3. 9. Descriptions

The description of adult female was based on all the listed types and other specimens examined. Usually, many specimens were examined but only the ones in good condition and representing the range of size of the characters were measured; the number measured in each species is specified.

3. 10. Distribution and host-plant data

Species distribution and host-plant data were taken from published works and specimen labels.

3. 8. Types and other material examined

The listed types and other material examined are all specimens on microscope slides. Much dry and spirit material was available and some slide-mounted specimens were prepared from each sample. Each specimen refers to one slide-mounted specimen. Sometimes there is more than one specimen per slide; the numbers cited refer to numbers of specimens not slides. The symbol '?' refers to the adult female unless otherwise specified.

3. 8. 1. Types

The type specimens listed have all been examined. Types were not borrowed for five species because they were either cosmopolitan or introduced species that have already been characterised and well defined: *P. elongata* (Williams, 1982), *P. psidii* (Hamon & Williams, 1984), *P. floccifera*, *P. hydrangeae* and *P. mesembryanthemi* (Gill, 1988). Type data were quoted from original labels, but some of the original labels lack information on the type locality and host plant. If the locality and the host plant were not on the label, these could usually be obtained from the original description and are explained in a separate paragraph immediately following the type listing. Maskell's original dry material and slides always lack this information. Deitz and Tocker (1980 p. 17) state: "Seldom did the original slides [of Maskell] have more information than scientific name, a date, and the initials "W. M. M." "

Some specimens were mounted from Maskell's dry material for the present study. Maskell's unmounted material (NZAC) is stored in small, cylindrical boxes (original), and in rectangular pill boxes (apparently supplied by Morrison) (Deitz and Tocker, 1980, p. 17), and therefore only the material from cylindrical boxes was regarded as type material. Any specimens in rectangular pill boxes were listed under 'Other material examined'.

3. 8. 2. Other material examined

The non-type material examined is listed after each description in alphabetical order of the states or territories, i. e., Australian Capital Territory, New South Wales, Northern Territory, Queensland, South Australia, Tasmania, Victoria and Western Australia. If specimens were from Australia but with no record of the exact locality, they were treated as locality unknown and listed last.

Within each state or territory, specimens are listed in alphabetical order of depositories, i. e., ANIC, BCRI, BMNH, DPI, MVM, NZAC, QM, SAM, TDA and WADA. The complete sequence for each sample is: number of specimens, host plant, locality, date, collector with collection number (where available) and depository with

index number (if depository index number available), e. g. 3 ♀, on *Myoporum deserti*, Condobolin, 26.xi.1978, M.J. Fletcher (BCRI). The stage of any immatures usually was not determined and therefore they are listed as immature except for the first instar nymphs which are easily recognised.

CHAPTER 4

GENERAL MORPHOLOGICAL DESCRIPTION OF THE ADULT FEMALE OF AUSTRALIAN PULVINARIINE SPECIES

4. 1. Body shape and anal cleft

The body (Fig. 1A) of the adult female is oval to broadly oval except that it is extremely elongate in *P. elongata* (Fig. 5A) and wider than long in *P. salicorniae* (Fig. 13A). The dorsal surface is often wider than the ventral surface as in *P. flavicans* (Fig. 6A) and *P. sp.n.* (Fig. 15A). The *anal cleft* is always less than one fifth the body length in the Australian species.

4. 2. Derm and sclerotisation

The *derm* is membranous in young adult females, but becomes slightly to heavily sclerotised at maturity. Some species have cell-like clear areas (Fig. 1D) on the dorsum which become sclerotised reticulations (Fig. 3A & D) in mature specimens. The mouthparts, legs, spiracles and anal plates are always sclerotised. Sclerotisation also occurs at the body margin in the spiracular furrows of some species and around the spiracles of other species.

4. 3. Segmentation

The ventral segmentation is detectable in the median and submedian areas of the body, while the dorsal derm has no signs of segmentation. As in other members of the family Coccidae, the head and the prothorax are fused together, and the abdomen and the metathorax cannot be distinguished in the submarginal areas.

Most abdominal segments are evident in the median and submedian areas because of the intersegmental lines. Williams & Kosztarab (1972) applied Ferris' (1955) theory (that the gonopore of coccoids lies on the eighth abdominal segment) to the Coccidae and recognised the second abdominal segment as the first visible one ventrally. They stated

that the ninth segment forms the anal plates, the tenth segment forms the anal ring and anal fold, and the eleventh segment is the membrane covering the anal opening.

4. 4. Body margin

4. 4. 1. Marginal setae

The *marginal setae* (Fig. 1B) are slender or stout and straight or curved. The apex of each marginal seta may be frayed or unfrayed. The frayed ones (Fig. 1B3) are bifid or branched and some of the latter are enlarged near the apex and then become dentate or fimbriate. The unfrayed ones are pointed (Fig. 1B1), expanded near the apex (Fig. 1B2), blunt (Fig. 1B4) or truncate (Fig. 1B5). Some marginal setae in *P. maskelli* have an enlarged base (Fig. 1B6).

The numbers of marginal setae are counted between the anterior spiracular furrows, between the anterior and posterior spiracular furrows of each side of the body, and between each posterior spiracular furrow and the anal cleft. These numbers represent the density and distribution of the marginal setae, and are of taxonomic value.

4. 4. 2. Spiracular setae

All Australian species have *spiracular setae* except *P. salicorniae* in which the spiracular setae are completely absent. There^{are} usually three spiracular setae (Fig. 1C1), however, *P. flavicans* has only one (Fig. 1C3) and *P. polygonata* has more than three (Fig. 11C). The hooked or J-shaped spiracular setae of *P. dodonaeae* (Fig. 1C2) are unusual for the Pulvinariini. The number, shape and ratio of the longest one to the remainder are all used to distinguish species.

Foldi & Pearce (1985) studied the fine structure of the spiracular setae in *P. regalis* Canard. They paid particular attention to the middle spiracular seta which produces wax along its length.

4. 4. 3. Spiracular sclerotisation

Spiracular sclerotisation is found at the body margin in each spiracular furrow of *P. dodonaeae*, *P. flavicans* and *P. thompsoni*. The plates are long and narrow (Fig. 1C2), small and triangular (Fig. 1C3) or large and triangular (Fig. 14C). Spiracular sclerotisation was recognised in some species of *Philephedra* (e.g. *P. crescentiae*) by Nakahara & Gill (1985). The only other coccid genus for which spiracular sclerotisation has been described is *Cryptostigma* Ferris (Ferris, 1922; Morrison, 1929; Steinweden, 1929; Qin & Gullan, 1989). However, the structure of the spiracular sclerotisation in *Cryptostigma* is different from that in *Pulvinaria*: the spiracular sclerotisations of *Cryptostigma* lack spiracular setae but they are associated with wax-exuding pores.

4. 5. Dorsum

4. 5. 1. Cell-like clear areas

Some species of Australian Pulvinariini have cell-like clear areas on the dorsum of young adult females, each 'cell' containing a microduct. These are well developed in *P. decorata* (Fig. 3D), *P. polygonata* (Fig. 11D) and *P. psidii* (Fig. 12D).

4. 5. 2. Dorsal setae

Dorsal setae (Fig. 1E) are usually short, spine-like and scattered. In *P. dodonaeae* the dorsal setae are extremely short (Fig. 4E) and rare. In *P. elongata* and *P. salicorniae* the dorsal setae are lanceolate (Figs 5E, 13E).

4. 5. 3. Submarginal tubercles and submarginal chambered ducts

Submarginal tubercles (Fig. 1F1) are present in four of the Australian species. They are larger than any pores, are distributed in the submarginal area around the body and are variable in number. The SEM structure of the submarginal tubercles in *Parthenolecanium persicae* (Fabricius) (formerly *Lecanium persicae*) was observed by Williams & Kosztarab (1972), who showed that the round tubercles surrounded a central

invaginated tube. The submarginal tubercles of Australian pulvinariine species are similar in structure to those of *P. persicae*.

Submarginal chambered ducts (Fig. 1F2) are a new character for the Pulvinariini. They are found in *P. dodonaeae* and are composed of a very long duct and a very slender inner filament with a chamber between. The opening of the submarginal ducts is usually associated with several pores and a very short seta. Nakahara & Gill (1985) described inverted duct tubercles in *Philephedra*. The inverted duct tubercles are distributed in the submarginal and/or submedian areas of the dorsum. In lateral aspect, the duct of the inverted tubercle appears as a long, central rod-like core. Both the submarginal chambered ducts and the inverted duct tubercles may have developed from the basic submarginal tubercles.

4. 5. 4. Disc pores and discoidal pores

Disc pores (Fig. 1G1) are usually scattered over the dorsum and have distinct circular rims and usually pale centres. They are called 'monolocular pores' in *Philephedra* (Nakahara & Gill, 1985).

Discoidal pores (Fig. 1G2) are larger than the disc pores and usually occur in a group in the median area anterior to the anal plates. In *P. dodonaeae* and *P. salicorniae* discoidal pores are in loose bands (Figs 4A, 13A) in the submedian area on each side of body from above the level of the antennal base or the second coxa to near the anal plates.

4. 5. 5. Tubular ducts

Tubular ducts (Fig. 1H) are found on the dorsum of all Australian Pulvinariini except *P. maskelli* and *P. thompsoni*. There are two types of tubular ducts. In most species, the ducts (Fig. 1H1) have slender inner filaments and are sparsely scattered over the dorsum. However, in *P. dodonaeae*, *P. flavicans* and *P. salicorniae*, the ducts (Fig. 1H2) possess a flowery tipped inner filament and are very numerous on the dorsum.

4. 5. 6. Microducts

Microducts (Fig. 1I) are scattered over the dorsum. These were called 'bilocular pores' by Williams & Kosztarab (1972). This terminology was not followed for two reasons. First, in the species studied here, these structures had a short duct plus either a slender inner filament (Fig. 1I1) or an expanded inner filament plus a long tail (Fig. 1I2). This is shown by Foldi's (1978, fig. 1) study on the ultrastructure of microducts on the dorsum of *Coccus hesperidum* L. Their structure is similar to that of the tubular ducts, and therefore they should be called 'ducts' rather than 'pores'. Second, it is difficult to determine whether their openings are monolocular or bilocular under the light microscope. The microducts are probably responsible for the secretion of fine filamentous wax on the dorsum, because *P. decorata* is almost covered by this kind of secretion dorsally and it possesses numerous microducts on the dorsum. Foldi & Pearce (1985) also found microducts in *P. regalis* and stated that these secrete 'lac resin'.

4. 5. 7. Anal plates and ventral thickenings

Anal plates (Figs 1J1, 2A) are located at the anterior end of the anal cleft. They are triangular in all Australian species, however, the shape of the lateral angle is variable. In *P. flavicans* and *P. dodonaeae*, the lateral angles are larger and more rounded than those in other species. In *P. maskelli* the dorsum of the anal plates is reticulated (Fig. 9J1).

Ventral thickenings (Fig. 1J2) are located internally between the dorsal and ventral surfaces and are sometimes difficult to discern. They are on the ventral side of each anal plate. The shape of each ventral thickening is triangular (Figs 6J2, 9J2), elongate triangular (Figs 3J2, 8J2) or narrow (Fig. 15J2). In *P. psidii* the two ventral thickenings (Fig. 12J2) are connected to each other in the midline.

There are several setae on the dorsum and venter of the anal plates. The three or four *apical setae* (Fig. 1J1) are dorsal and located at or close to the posterior angle of each plate. In *P. hydrangeae*, one seta has moved away from the other apical setae to the subdiscal area and is called the *subdiscal seta* (Figs 1J1, 8J1). The inner margin of the

anal plates has one or two setae in some Australian species, and these are termed *inner margin setae* (Fig. 1J1) in the present work. The subapical and fringe setae are on the venter of the anal plates. The *subapical setae* (Fig. 1J2) number one to three on each anal plate. There are usually two pairs of *fringe setae* (Fig. 1J2) at the anal fold.

4. 5. 8. Anal ring

The anal apparatus is a device for propulsion of excrement away from the insect's body (Williams & Williams, 1980), and possesses an eversible anal invagination with the anal ring (Fig. 1K) at the inner end of the whole apparatus. The *anal ring* is surrounded by usually six or eight anal setae and one to three rows of translucent pores. If there are eight anal setae, then one pair is smaller than the others. The anal setae are coated by wax filaments produced by the numerous small glands whose openings are the translucent pores, and these setae play a catapult role in the process of disposal of the excrement (Foldi & Pearce, 1985).

4. 6. Venter

4. 6. 1. Setae

There are submarginal setae, ventral setae, interantennal setae and prevulvar setae on the ventral surface.

The *submarginal setae* (Fig. 1L) are distributed as a row in the submarginal area around the entire body. They are usually slender, acute and straight or slightly curved. The submarginal setae are always many fewer in number than the marginal setae.

The *ventral setae* (Fig. 1M) are usually scattered over the venter but paired on each segment in the median area. They are similar to the submarginal setae. The paired setae in the median area are usually longer than others. The ventral setae usually occur in groups around the vulva and near the base of each coxa.

Both interantennal and prevulvar setae are similar structurally to the ventral setae. There are two to seven pairs of *interantennal setae*. Usually some are much larger and longer than the ventral setae, and others are almost the same size as the ventral setae. The

prevulvar setae consist of one to three pairs anterior to the vulva. They are all longer and larger than the ventral setae.

4. 6. 2. Eyes

The eyes are detectable in some Australian species. They are broadly oval and located near the body margin anterior to the level of the antennal bases.

4. 6. 3. Antennae

All Australian pulvinariine species have well developed antennae. The antennae (Fig. 1N) are usually eight-segmented, but some species have six-, seven- (Fig. 13N) or nine-segmented antennae. The first segment is the widest and usually has three setae. The second segment always has a very long seta near its apex and possesses a sensory pore which was called a 'campaniform sensillum' by Koteja (1980). The third segment is usually the longest. The apical segment has two to eight fleshy setae called 'thin-walled pegs' by Koteja (1980) and two to eight slender, hair-like setae. The two subapical segments are usually the shortest and each of them always has one fleshy seta. Each of the other segments, if present, usually has one to three hair-like setae.

The segmentation of the antennae is often variable within a species. Sometimes the number of antennal segments on one side of the body of an individual is different from that on the other side. The increase or reduction of antennal segments seems to occur always at the third subapical segment where signs of segment fusion (Figs 1N, 13N) may be visible.

4. 6. 4. Mouthparts

The mouth parts are located between the bases of the first pair of legs and are composed of the clypeolabral shield, the stylets, and the labium.

The *clypeolabral shield* of scale insects was studied by Koteja & Liniowska (1976) who discussed its taxonomic value and figured it for three species of Pulvinariini, including *P. vitis* (the type species of *Pulvinaria*) and *Chloropulvinaria floccifera* (=P.

floccifera) (which occurs in Australia). The shape of the clypeolabral shield in all but two Australian species is similar to that of the three species drawn by Koteja & Liniowska (1976, fig. 10). The exceptions are *P. dodoneae* and *P. salicorniae* in which the clypeolabral shield appears similar to that of *Vittacoccus longicornis* (Green) (Ibid, fig. 9).

The *stylet bundle* is fairly short and looped in all the Australian Pulvinariini. The *labium* is conical and one-segmented and there are always four setae on each side. Koteja (1974) included *Pulvinaria* species in his study of the coccoid labium. He (Koteja, 1976) also investigated the *salivary pump* of Coccoidea and included *P. floccifera*.

4. 6. 5. Legs

The *legs* of all Australian species are well developed, although in *P. elongata* and *P. flavicans* the legs are small in comparison to the body size. Each leg is composed of five segments: coxa, trochanter, femur, tibia and tarsus with a single claw. There are several setae on the dorsal and ventral surface of each leg segment. The trochanter is triangular and always has two sensory pores ('sensilla placodeum' of Koteja (1974a, fig. 1C)) and a very long seta. The tibiotarsal sclerotisation (Fig. 1O1 & 2) is present in all species except *P. flavicans*. Free articulation of the tibia and tarsus is usually associated with possession of tibiotarsal sclerotisation (Fig. 1O1), except in *P. elongata* in which only tibiotarsal sclerotisation (Fig. 1O2) is present. The tarsus always has a pair of slender and knobbed digitules. The claw has a pair of usually broader digitules which are expanded near the apex. The claw digitules are slender in *P. flavicans* and *P. salicorniae*. A claw denticle is present only in *P. dodoneae* and *P. flavicans*.

4. 6. 6. Spiracles

The two pairs of thoracic spiracles are similar in structure, but the anterior ones are smaller than the posterior ones in all Australian Pulvinariini. Williams & Kosztarab (1972) stated that the anterior spiracles are on the borderline between the

prothorax and mesothorax and the posterior spiracles are between the mesothorax and metathorax in the Coccidae. The spiracles of the Australian pulvinariine species may be slender (Fig. 11P) or stout (Fig. 15P), but there is some variation within species. The width across the atrium may be greater (Fig. 10P) or less than (Fig. 12P), or almost the same width as (Fig. 6P) that across the apodeme. In *P. decorata*, *P. polygonata* and *P. psidii*, each spiracle is surrounded by a sclerotic plate (Fig. 1P2) in mature specimens.

4. 6. 7. Spiracular pore bands and spiracular pores

There are four *spiracular pore bands* in the Pulvinariini and each of them extends from the body margin to a spiracle. The spiracular pore bands in *P. salicorniae* are up to eight pores wide at the margin which contrasts with those in other species.

The *spiracular pores* in the spiracular pore bands are quinquelocular (Fig. 1Q3) but occasionally, 3 and/or 4 loculi (Fig. 1Q1 & 2) are found in some pores. Foldi & Pearce (1985) studied the fine structure of the spiracular pores of *P. regalis* and stated that the spiracular pores produce a white hydrophobic wax secretion that protects the air passage leading to the spiracles.

4. 6. 8. Multilocular pores

Multilocular pores (Fig. 1R) are distributed around the vulvar area, in transverse bands on all or at least the posterior abdominal segments, and usually in a group beside each hind coxa. In *P. elongata*, one to two multilocular pores are distributed between each antennal base and the mouthparts. Each multilocular pore has a central loculus and an outer ring of six to 12 loculi. The loculi produce curled C-shaped wax strands that break off into shorter strands which coat the eggs (Foldi & Pearce, 1985).

A second type of multilocular pore (Figs 1R2, 2B) is found in *P. dodonaeae*, *P. hydrangeae* and *P. salicorniae*. This has a small slit in the central loculus. This structure has also been noticed in *P. regalis* by Canard (1968a, fig. 2) and in *P. hydrangeae* by Gill (1988, fig. 37).

In *P. flavicans*, the structure of the multilocular pores (Fig. 1R3) is unusual. The outer ring of loculi cannot be seen under the light microscope, the central loculus has expanded and there is a well developed middle partition. Under SEM, the outer ring of loculi (Fig. 2C, D arrowed) can be determined and the partition projects vertically and bears a groove-like slit in the middle. This kind of multilocular pore may have developed from the second type by projection of the central area and reduction of the slit.

4. 6. 9. Tubular ducts

Tubular ducts are numerous on the venter. There are two types of tubular ducts. The first type (Figs 1S1, 2E) has a slender inner filament and is distributed mainly in the submarginal area. The second type (Fig. 1S2, 2F) has a flowery tipped inner filament and is distributed usually in the median and submedian areas. The thickness of the inner filament in the second type is variable within and/or between species (Fig. 1S2): either slender, half as wide as, as wide as or wider than the duct itself. In *P. psidii*, some tubular ducts (Fig. 1S3) have a very long inner filament and a very short duct. The distribution and the density of the tubular ducts also vary from species to species, but usually ducts are numerous in the submarginal area of the venter. Williams (1982) calls the ventral tubular ducts of the grass-infesting *Pulvinaria* 'submarginal ducts' because they mostly occur in the submarginal area.

Steinweden (1929, 1946) stated that the tubular ducts in *Pulvinaria* species probably produce the ovisac. This was confirmed by Foldi & Pearce (1985) for *P. regalis* in which the tubular wax gland, composed of two types of glandular cells, produces a long white filament that is associated with the construction of the ovisac.

4. 6. 10. Microducts

Microducts (Fig. 1T) are scattered over the venter and are usually numerous in the submarginal area. Both the ducts and the expanded inner filament are usually very short. However, in *P. salicorniae* the microducts have a very long inner filament (Fig. 1T5) and in *P. maskelli* the duct of the microducts (Fig. 1T4) is fairly long

and the inner filament has three finger-like projections. In *P. dodonaeae*, *P. flavicans* and *P. thompsoni* the inner filament is bulbous or dumb-bell shaped (Figs 1T2 & 3, 2G & H). The opening of the microducts is barely visible under the light microscope.

4. 6. 11. Vulva

Williams & Kosztarab (1972) stated that the vulva of coccids, although very difficult to detect, is located on abdominal segment VIII anterior to the anal cleft. It has not been drawn on any of the figures in the present work because it was only discerned in two specimens.

CHAPTER 5

TAXONOMY OF THE AUSTRALIAN PULVINARIINE SPECIES

5. 1. Definition of the tribe Pulvinariini

The tribe Pulvinariini appears to be polyphyletic (see Chapter 6) and is poorly defined morphologically. The tribe has been weakly diagnosed by its field characteristic: those Coccidae in which the female, during oviposition, forms a white ovisac which projects from the abdomen and is found behind or beneath the body. Borchsenius (1957, p. 202) has provided a morphological diagnosis and the main characters are: body oval, sometimes asymmetric; marginal setae well developed, some serrate and forked at apex; spiracular setae well developed, median one often significantly longer than lateral ones; dorsal setae present or absent; ventral setae always present; antennae and legs well developed, legs usually with tibiotarsal sclerotisation; multilocular pores present; tubular ducts arranged in a wide submarginal band on venter.

There are currently 26 genera in the Pulvinariini (see Appendix B) but no key is available to the world genera. Borchsenius (1957, p. 202-203) has provided a key to eleven genera of the Palaearctic Pulvinariini, but many of Borchsenius' generic concepts have not been accepted by American authors (see Chapter 2). A key to six genera of North American Pulvinariini has been provided by Nakahara & Gill (1985, p. 4).

5. 2. Taxonomic position of the Australian species

The modern generic concepts of non-American authors have already been applied to some Australian species, viz: *P. floccifera*, *P. polygonata* and *P. psidii* have been placed in *Chloropulvinaria* Borchsenius (1952, 1957); *P. mesembryanthemi* in *Pulvinariella* Borchsenius (1953); *P. hydrangeae* in *Eupulvinaria* Borchsenius (Canard, 1965); *P. elongata* in *Sacharipulvinaria* Tao, Wong & Chang (1983, by indication). Three of the other Australian species also could be fitted into Borchsenius' (1957) system: *P. decorata* and *P. sp. n.* in *Chloropulvinaria* and *P. thompsoni* possibly in *Pulvinariella* except that it has spiracular sclerotisation and too many marginal setae.

Other species do not fit satisfactorily into any existing genera. Nevertheless, the presence of numerous tubular ducts on the dorsum makes *P. dodonaeae* and *P. flavicans* similar to *Metapulvinaria* and the marginal setae of *P. maskelli* place it close to *Megapulvinaria*, although the latter has more than three spiracular setae. The affinities of *P. salicorniae* are difficult to determine: its marginal setae resemble those of *Pulvinariella*, but the absence of spiracular setae makes it similar to *Mesembryna*, and the numerous tubular ducts on the dorsum are similar to those of *Metapulvinaria*.

All Australian species are retained in the genus *Pulvinaria* in the present study. This decision has been made because phylogenetic relationships between genera in the Pulvinariini are still unknown (see Chapter 6) and the existing generic framework is considered inadequate. In addition, four Australian species are peculiar and cannot fit into any existing genera. If the current practice of erecting new genera for species with unique attributes were to be followed, then four monotypic genera would have to be established. Any splitting will cause only more confusion in the future and therefore a taxonomically conservative approach has been followed in this work, and new genera were not created for these four species.

5. 3. Genus *Pulvinaria* Targioni-Tozzetti

Genus *Pulvinaria* Targioni-Tozzetti

Pulvinaria Targioni-Tozzetti, 1866, p. 146. Type species: *Coccus vitis* Linnaeus, 1758, by original designation and monotypy.

A generic description of the genus *Pulvinaria* is not presented here because: (i) the concept of *Pulvinaria* is still controversial (see Chapter 2, Chapter 6); (ii) the Australian pulvinariine species may not be congeneric although they are all retained in the genus *Pulvinaria* in the present study (see above); and (iii) a general morphological description of the adult females of all Australian species has already been provided (Chapter 4).

5. 4. Key to adult females of Australian species of *Pulvinaria*

- 1 All marginal setae with apex blunt, truncate or rounded, never notched
-----2
- All or many marginal setae with apex notched, bifid or fimbriate --- 8
- 2(1) Tubular ducts numerous dorsally, duct with flowery tipped inner
filament -----3
- Tubular ducts absent dorsally or only a few scattered, duct with
slender, not flowery tipped inner filament -----5
- 3(2) Spiracular setae absent; body usually wider than long -----
----- *salicorniae* Froggatt (p. 85)
- Spiracular setae present; body never wider than long -----4
- 4(3) Submarginal chambered ducts present; 3 spiracular setae -----
----- *dodonaee* Maskell (p. 37)
- Submarginal chambered ducts absent; 1 spiracular seta -----
----- *flavicans* Maskell (p. 47)
- 5(3) Body elongate, length always more than twice width; tubular ducts in
distinct submarginal band on venter around entire body -----
----- *elongata* (Newstead) (p. 42)
- Body usually oval to broadly oval, length usually less than twice
width; tubular ducts not in distinct submarginal band on venter
around entire body -----6
- 6(5) Marginal setae truncate; anal plates with dorsal reticulations -----
----- *maskelli* Olliff (p. 62)
- Marginal setae never truncate; anal plates without reticulations -----7
- 7(6) Spiracular sclerotisation present, triangular or horseshoe-shaped;
median spiracular setae usually less than 3 times length of lateral
ones----- *thompsoni* Maskell (p. 89)

- Spiracular sclerotisation absent; median spiracular setae usually more than 3 times length of lateral ones -----
----- *mesembryanthemi* (Vallot) (p. 71)
- 8(1) Submarginal tubercles present ----- 9
- Submarginal tubercles absent ----- 12
- 9(8) Dorsum with cell-like clear areas; some or all spiracles surrounded by sclerotic plate; 3 subapical setae on each anal plate ----- 10
- Dorsum without cell-like clear areas; spiracle not surrounded by sclerotic plate; 2 subapical setae on each anal plate -----
----- *floccifera* (Westwood) (p. 53)
- 10(9) Spiracular setae more than 3; marginal setae deeply branched -----
----- *polygonata* Cockerell (p. 76)
- Spiracular setae always 3; marginal setae not deeply branched ---- 11
- 11(10) Marginal setae short (12-40 μm), all finely toothed; some tubular ducts on venter with very long inner filament (28-42 μm); ventral thickenings connected to each other medially -----
----- *psidii* Maskell (p. 80)
- Marginal setae long (30-100 μm), only some toothed; tubular ducts on venter with inner filament only 15-20 μm long; ventral thickenings not connecting to each other medially -----
----- *decorata* Borchsenius (p. 33)
- 12(8) Subdiscal seta present; tubular ducts numerous all over venter -----
----- *hydrangeae* Steinweden (p. 58)
- Subdiscal seta absent; tubular ducts absent from submarginal area of head and thorax of venter ----- sp. n. (p. 93)

5. 5. Descriptions of species

Pulvinaria decorata Borchsenius

(Fig. 3)

Pulvinaria ornata Froggatt, 1921, p. 427 (nec. Hempel, 1912, p. 61)

Pulvinaria decorata Borchsenius, 1957, p. 228 (nom. nov.)

Froggatt's (1921) species name *Pulvinaria ornata* had been preoccupied by another species from Brazil (*P. ornata* Hempel, 1912, p. 61), therefore Borchsenius (1957, p. 228) replaced it with *P. decorata*.

Suggested common name: Lemon cottony soft scale

Types

Lectotype of *Pulvinaria ornata* (present designation): ♀, New South Wales, 4 labels: "*Pulvinaria, ornata*, Frogg., Lemon, Sydney" "1033, Whenholly", "1920, 1.11" and "W.W.Froggatt, 25.i.1921" (BCRI). **Paralectotype** (present designation): 1 immature ♀, same data as lectotype (BCRI).

Diagnosis

Appearance: Adult female almost covered by fine wax, often only posterior edge and sometimes median area visible; body yellow-brown, about 4.0 mm long, 2.5 mm wide. Ovisac white, 2.5-4.0 mm long, 2.6-4.0 mm wide, slightly convex, with 5 longitudinal furrows, and middle furrow distinctive.

Slide-mounted adult female: Dorsum with cell-like reticulations; some marginal setae expanded near apex; 3 subapical setae on each anal plate; spiracles often surrounded by sclerotic plate; anal ring with 6 setae.

Description of adult female (4 slide-mounted specimens measured, Fig. 3)

Body (Fig. 3A) oval to broadly oval, 3.9-4.4 mm long, 2.5-3.0 mm wide, length 1.3-1.8 times width. *Anal cleft* 500-560 μm long, 0.12-0.13 body length.

Margin: Marginal setae (Fig. 3B) 28-62 μm long, slender, straight or curved, some bluntly pointed, some bifid or fimbriate, some expanded near apex; distributed as follows: 77-85 between anterior spiracular furrows, 24-27 between anterior and posterior spiracular furrows on each side, 55-68 between each posterior spiracular furrow and anal cleft. *Spiracular setae* (Fig. 3C) 3 in each spiracular furrow; median seta 55-70 μm long, 2.2-3.9 times as long as lateral setae, straight or slightly curved, bluntly pointed; lateral setae 15-25 μm long, straight, bluntly pointed. *Spiracular sclerotisation* absent.

Dorsum: Derm (Fig. 3A, D) with cell-like clear areas and becoming reticulations in old specimens. *Dorsal setae* (Fig. 3E) 7-10 μm long, spine-like, scattered over dorsum. *Submarginal tubercles* (Fig. 3F) 11-14 around body, 9-12 μm in diameter. *Disc pores* not detectable. *Discoidal pores* (Fig. 3G) 4-5 μm in diameter, in group of 32-40 in median area anterior to anal plates. *Tubular ducts* (Fig. 3H) scattered; duct 7-12 μm long, 3 μm wide, inner filament 4-10 μm long. *Microducts* (Fig. 3I) distributed in cell-like clear areas; duct 2 μm long, 1 μm wide, inner filament not visible in available specimens. *Anal plates* (Fig. 3J1) each triangular, 145-160 μm long, 80-88 μm wide; anterolateral margin slightly concave, 100-107 μm long, posterolateral margin convex, 110-123 μm long. Each plate with 4 apical setae 10 μm long, 3 subapical setae 40-75 μm long, and no inner margin setae. *Ventral thickening* (Fig. 3J2) elongate triangular. *Fringe setae* 2 pairs, 55-105 μm long. *Anal ring* 55-80 μm wide (length not measured due to orientation), with 6 setae 210-250 μm long; translucent pores in 1-3 rows, each pore oval, 4-6 μm in maximum dimension.

Venter: Submarginal setae (Fig. 3L) 10-17 μm long, slender, acute, mostly straight; distributed as follows: 23-31 between anterior spiracular furrows, 7-8 between anterior and posterior spiracular furrows on each side, 22-26 between each posterior spiracular furrow and anal cleft. *Ventral setae* (Fig. 3M) 12-80 μm long, similar to submarginal setae, setae paired and longer in median area on each segment. *Interantennal*

setae 3-4 pairs, 38-180 μm long. *Prevulvar setae* 3 pairs, 130-185 μm long. *Eyes* not detectable. *Antennae* (Fig. 3N) well developed, 8 segmented, 455-525 μm long, third segment longest; segment I 70-90 μm wide, 40-60 μm long; length of segments II to VIII: 80-85 μm , 100 μm , 50-70 μm , 60-70 μm , 30-35 μm , 25-28 μm and 60 μm , respectively; number of hair-like setae: I, 3; II, 2; III, 1-2; IV, 0-2; V, 2-3; VI, 0; VII, 1; VIII, 5; number of fleshy setae: VI, 1; VII, 1; VIII, 5. *Clypeolabral shield* 170-200 μm long, 160-200 μm wide. *Labium* 65-70 μm long, 100 μm wide, with 4 setae 27 μm long on each side. *Legs* (Fig. 3O) well developed, with tibiotarsal sclerotisation and free articulation; claws without denticle; tarsal digitules slender, knobbed, 70-75 μm long; claw digitules broad, equal, expanded at apex, 42-50 μm long.

Leg lengths as follows:

Segments	First leg (μm)	Second leg (μm)	Third leg (μm)
Coxa	110-120	125-130	130-140
Tro.+Fem.	280-290	320-350	310-330
Tibia	215-220	220-240	230-250
Tarsus	100-110	110-115	110-120
Claw	30	30-32	30-32
Total	740-755	805-842	810-862

Anterior spiracles (Fig. 3P) each 70-80 μm long, 45-75 μm wide across atrium, atrium wider than apodeme. *Posterior spiracles* similar to anterior ones, each 80-90 μm long, 50-70 μm wide across atrium. *Spiracular pore bands* loose, each 1-3 pores wide, extending slightly beyond apodemal base of spiracles. Spiracles surrounded by sclerotic plate in mature specimens. *Spiracular pores* (Fig. 3Q) quinquelocular, 4-5 μm in diameter, 63-65 in anterior spiracular pore band, 71-88 in posterior spiracular pore band. *Multilocular pores* (Fig. 3R) 7 μm in diameter, 6-12 loculi, around anal area, in transverse bands on abdomen and a few beside each coxa. *Tubular ducts* of 2 types: first (Fig. 3S1) with slender, knobbed filament, numerous in submarginal areas, duct 10 μm long, 3 μm wide, inner filament about 8 μm long; second (Fig. 3S2, S3) with

flowery tipped inner filament, distributed in median and submedian areas, duct 10-13 μm long, 3-4 μm wide, inner filament 18-42 μm long, 1-3 μm wide, flowery apex 3-6 μm wide. *Microducts* (Fig. 3T) scattered, 4 μm long, 2 μm wide.

Other material examined

Locality unknown: 3 ♀ (2 remounted), labelled: "*Pulvinaria ornata* Frogg." [not Froggatt's handwriting] (BCRI)

Distribution and host plants

This species has been recorded only from the Sydney area (Froggatt, 1921).

Although Froggatt (1921) described this species based on specimens from a lemon tree, he suspected that its original or natural host plant was *Pittosporum undulatum*, from which the insects had migrated to the lemon tree (Froggatt, 1921, p. 428).

Discussion

The shape of some marginal setae and the distribution of the ventral tubular ducts of *P. decorata* are similar to those of *P. floccifera*, *P. hydrangeae*, *P. polygonata* and *P. psidii*. However, *P. decorata* differs from all of these species by having some marginal setae expanded near the apex (Fig. 3B). Moreover, *P. decorata* is different from *P. floccifera* in having cell-like reticulations on the dorsum, three subapical setae instead of two and some spiracles surrounded by a sclerotic plate. The possession of submarginal tubercles and the absence of subdiscal setae distinguishes *P. decorata* from *P. hydrangeae*. *Pulvinaria decorata* has three spiracular setae instead of more than three in *P. polygonata*, and it has longer marginal setae with only some of them toothed compared with *P. psidii* which has shorter and all finely toothed marginal setae.

Pulvinaria decorata is very similar to *P. neocellulosa* Takahashi (1940) from Taiwan. In the descriptions and illustrations of *P. neocellulosa* by Takahashi (1940) and

Tao *et al.* (1983), the marginal setae are never frayed and the body shape is elongate, but in *P. decorata* some marginal setae are frayed and the body shape is oval to broadly oval.

***Pulvinaria dodonaeae* Maskell**

(Figs 2A & B, 4)

Pulvinaria dodonaeae Maskell, 1893, pp. 222-223, pl. xiii figs 8, 9; Fernald, 1903, p. 132; Froggatt, 1915, p. 414; 1921, p. 8.

Pulvinaria greeni Froggatt, 1915, p. 415, pl. viii fig. 4; 1921, p. 9, fig. 4. New

Synonymy

Suggested common name: Hopbush cottony soft scale

Types

Lectotype of *Pulvinaria dodonaeae* (present designation): ♀, Australia, labelled: "*Pulvinaria, dodonaeae*, adult female, 1892 W. M. M" (ANIC from NZAC; Maskell's original slide). **Paralectotypes** (present designation): 1 ♀, 1 anterior part of ♀, 1 immature ♀, and 8 first instar nymphs on one slide, all same data as lectotype (NZAC; Maskell's original slides); 3 ♀, ex dry material in cylindrical box, label on lid: "*Pulvinaria, dodonaeae*, ♀s and ♂s, Australia" (NZAC; Maskell's original specimens); Additional dry material in cylindrical box, same data as above (NZAC);

Maskell's original slides and dry material have no locality or host plant data, but in his original description, Maskell (1893, p. 223) stated: "In Australia, on *Dodonaea bursarifolia* and *Myoporum* sp. My specimens are from Mr. Tepper". According to this statement, the type specimens may be from two genera of host plants (and possibly two localities); Maskell didn't specify whether his description was based on specimens from only one host. Fortunately, all the specimens examined here are identical. The dry material kept in SAM is obviously part of the type material, and the host plant is *D. bursarifolia*, although labelled both *D. bursarifolia* and *Myoporum* sp.

Lectotype of *Pulvinaria greeni* (present designation): ♀, ex dry piece of bark, 3 labels: "Myoporum deserti, Condobolin 15.11.99. W. W. F.", "307" and "Type, WWF, Cat II 96, 1921" (BCRI). **Paralectotype** (present designation): 1 ♀, same data as lectotype (BCRI); Additional dry material in tray, same data as lectotype (BCRI); 1 ♀, remounted from Froggatt's original slide labelled: "*Pulvinaria, greeni*, n. sp." (BCRI).

Diagnosis

Appearance: Adult female dark-brown, shrivelled, corrugated, 2.0-3.8 mm long, 1.5-2.5 mm wide. Ovisac white, 1.5-3.0 mm long, 2.0-3.0 mm wide, convex, covering marginal and submarginal areas of dorsum, with 2 distinct longitudinal furrows.

Slide-mounted adult female: With an obvious narrow spiracular sclerotisation in each spiracular furrow; spiracular setae stout, J-shaped; submarginal chambered ducts around entire margin of body; tubular ducts numerous on dorsum and venter; each claw with a small denticle.

Description of adult female (13 slide-mounted specimens measured, Fig. 4)

Body (Fig. 4A) oval to broadly oval, 1.7-4.0 (3.0 ± 0.6) mm long, 1.4-2.4 (1.8 ± 0.6) mm wide, length 1.2-1.7 times width. Anal cleft 120-300 (225 ± 54) μ m long, 0.06-0.09 body length.

Margin: *Marginal setae* (Fig. 4B) 15-40 μ m long, stout, mostly curved, bluntly pointed; distributed as follows: 46-110 between anterior spiracular furrows, 21-39 between anterior and posterior spiracular furrows on each side, 55-101 between each posterior spiracular furrow and anal cleft. *Spiracular setae* (Fig. 4C) 2-4 (mostly 3) in each spiracular furrow, 13-40 μ m long, hooked or J-shaped, apex blunt. *Spiracular sclerotisation* (Fig. 4C) present, narrow.

Dorsum: *Dorsal setae* (Fig. 4E) about 3 μ m long, spine-like, rare. *Submarginal tubercles* absent, but *submarginal chambered ducts* (Fig. 4F) present, 9-27 (mostly 18-24) around entire margin, duct 20-40 μ m long, 5-6 μ m wide, inner filament 8-16 μ m long, very thin with cone between; 0-8 (mostly 3-5) pores associated with opening of

duct, opening always toward to margin. *Disc pores* (Fig. 4G1) 3-4 μm in diameter, scattered. *Discoidal pores* (Fig. 4G2) circular, oval or irregular in shape, 5-9 μm in maximum dimension, in loose band in submedian area of each side of body extending from near anal plates to level of antennal base. *Tubular ducts* (Fig. 4H) with flowery tipped inner filament, numerous in marginal and submarginal area around entire body; duct 10-15 μm long, 4 μm wide, inner filament 10-15 μm long, 2 μm wide, flowery apex 3 μm wide. *Microducts* (Fig. 4I) numerous over dorsum; about 2 μm long, 2 μm wide, inner filament 2 μm long. *Anal plates* (Figs 2A, 4J1) each triangular, lateral angle more rounded, 125-195 (175 ± 20) μm long, 60-80 (70 ± 7) μm wide; anterolateral margin usually convex or slightly concave, 75-85 (81 ± 5) μm long; posterolateral margin usually concave or straight, 125-155 (139 ± 11) μm long. Each plate with 3 apical setae, lateral one shortest, 20-25 μm long, others each 35-50 μm long, 1 inner margin seta 25-50 μm long; 3 subapical setae 30-65 μm long. *Ventral thickenings* (Fig. 4J2) elongate triangular. *Fringe setae* 2 pairs, 78-95 μm long. *Anal ring* (Fig. 4K) circular or subcircular, 60-75 (70 ± 6) μm long and 60-75 (70 ± 6) μm wide, with 8 setae 115-335 μm long; translucent pores in 1-2 rows, each pore 3-5 μm in maximum dimension.

Venter: *Submarginal setae* (Fig. 4L) 8-15 μm long, slender, acute and usually straight; distributed as follows: 11-18 between anterior spiracular furrows, 3-4 between anterior and posterior spiracular furrows on each side, 9-16 between each posterior spiracular furrow and anal cleft. *Ventral setae* (Fig. 4M) 8-12 μm long, similar to submarginal setae. *Interantennal setae* 3-4 pairs, 1 pair longest, 18-50 μm long, others similar to ventral setae. *Prevulvar setae* 1 pair, 80-110 μm long. *Eyes* not detected in available specimens. *Antennae* (Fig. 4N) well developed, 6-8 (mostly 7) segmented, 290-385 (346 ± 33) μm long, usually fourth segment longest (for 7-segmented specimens); segment I 60-75 (69 ± 6) μm wide, 35-70 (52 ± 11) μm long; length of segments II to VII: 40-55 (49 ± 5) μm , 50-70 (64 ± 9) μm , 55-90 (80 ± 12) μm , 25-40 (30 ± 5) μm , 20-40 (29 ± 5) μm and 35-50 (43 ± 5) μm , respectively; number of hair-like setae: I, 3; II, 1-3; III, 0; IV, 1-3; V, 0; VI, 0-1 and VII, 1-2; number of fleshy setae: V, 1; VI, 2 and VII, 5-7. *Clypeolabral shield* 210-260 (237 ± 21) μm long, 130-190

(165±17) µm wide. *Labium* 45-75 (63±9) µm long, 90-120 (103±10) µm wide, with 4 setae 20-35 µm long on each side. *Legs* (Fig. 4O) well developed, with tibiotarsal sclerotisation and free articulation; claws with denticle near tip; tarsal digitules slender, knobbed, 58-70 µm long; claw digitules broad, expanded at apex, 35-45 µm long. Leg lengths as follows:

Segments	First leg (µm)	Second leg (µm)	Third leg (µm)
Coxa	90-130 (112±13)	110-160 (128±15)	110-150 (131±14)
Tro.+Fem.	218-290 (252±26)	240-310 (277±26)	230-315 (278±28)
Tibia	138-220 (184±25)	175-245 (216±26)	175-245 (224±26)
Tarsus	80-120 (103±16)	80-145 (123±21)	95-150 (126±17)
Claw	25-35 (31±4)	25-35 (32±4)	25-35 (32±4)
Total	561-795 (682±81)	633-880 (781±85)	635-875 (796±84)

Anterior spiracles (Fig. 4P) each 55-80 (68±84) long, 35-50 (43±5) µm wide across atrium, atrium usually same wide as apodeme. *Posterior spiracles* similar to anterior ones, each 60-90 (73±11) µm long, 40-55 (48±5) wide across atrium. *Spiracular pore bands* each 2-3 pores wide, extending to spiracular apodemal base. *Spiracular pores* (Fig. 4Q) quinquelocular, 5 µm in diameter, 33-41 in anterior spiracular pore band, 35-55 in posterior spiracular pore band. *Multilocular pores* (Fig. 4R) 6-10 µm in diameter, 6-12 (mostly 10) loculi, central loculus with slit (Fig. 2B), around anal area, and in transverse bands at abdomen, in group in submedian area of abdomen, some beside each coxa of second and third legs. *Tubular ducts* (Fig. 4S) with flowery apex, not as numerous as on dorsum but distributed over venter, duct 10-32 µm long, 4 µm wide, inner filament 8-22 µm long, 2-3 µm wide, flowery apex 3-6 µm wide. *Microducts* (Fig. 4T) rare and scattered, bulbous, 5 µm long, 1.5 µm wide.

Other material examined

New South Wales: 2 ♀ on one slide, on *Ardisia crispa*, Rydalmere, 21.xi.1966, C. Chadwick (ANIC); 1 ♀, on *Eremophila mitchellii*, Gongolgon, S. of

Brewarrina, 16.x.1980, B. Hitchen (ANIC: WARI No. 25/80); 2 ♀, West Wyalong, 26.xi.1978, M.J. Fletcher (BCRI); 1 ♀, on emu bush, Nyngan, 31.v.1979, D.F. Thompson (BCRI); 5 ♀, on *Eremophila mitchellii*, Gongolgon, S. of Brewarrina, 16.x.1980, B. Hitchen (BCRI); 2 ♀, on *Eremophila mitchellii*, Leadknapper Ck, 80 km N.E. Bourke, v.1982, D. J. Johnston (BCRI); 7 ♀ (1 ♀/slide except one slide with 4 ♀), on *Myoporum deserti*, Condobolin, W.W.Froggatt No. 301 (BMNH). **Northern Territory:** 4 ♀, (2 ♀/slide), on *Acacia* sp, Mt. Olga, 12. vi 1953, P.E. Madge (ANIC: WARI No. 127/ 56); 8 ♀, on ? *Acacia*, Mt. Olga, 12. vi. 1956, P.E. Madge (ANIC: WARI No. 128/56). **Queensland:** 2 ♀, 1 immature, on leaves of *Eremophila longifolia*, St. George, 19. ii. 1960, J.F.D.1757 (DPI); 4 ♀, 9 male, 6 male pupa on five slides (3+4+3+5+4/slide), on *Eremophila gilesii*, Charleville, 4.iii.1970, W.H. Burrows (DPI); 3 ♀, ex sandalwood, "Koomerang", Cunnamulla, 19. v. 1980. L.N. Corbet (DPI); 2 + 4 immature ♀ on 1 slide, 37 immature on another slide, ex hopbush "Koomerang" Cunnamulla, 19.v.1980. L. N. Corbet (DPI). **South Australia:** 7 ♀ on one slide, from leaves of *Myoporum*, 16. ii. 1955. D.C.S. (ANIC: WARI No. 23/55). 6 ♀ (3 ♀/slide), on leaves of ? *Myoporum*, Waikerie, xii. 1958. (ANIC; WARI E39/58); 2 ♀ on one slide, on leaves of *Myoporum*, Blanchetown, 23. iii. 1965, D. E. Symon (ANIC: WARI No. 10/65); 26 ♀ (4 ♀/slide except two slides each with 3 ♀ and another two slides each with 2 ♀), on *Dodonaea attenuata*, nr. Loxton, 16.x.1974, M. Carver (ANIC: WARI No. 8/74); 9 ♀ (2 ♀/slide except one slide with 3 ♀), on *Dodonaea attenuata*, nr. Loxton, 12.xi.1974, H.M. Brookes (ANIC: WARI No. 8/74); 6 ♀ (3 ♀/slide), on *Acacia* sp. Loxton, 23.xi 1977, R.Obst (ANIC; L867); 7 immature (3+4/slide), on *Myoporum*, River Murray Valley, nr. Mannum, 22.iv.1979. D.E.Symon (ANIC); 2 ♀ on one slide, on *Dodonaea* sp., 30. xi.1967, L.A. Mound (BMNH; 1968-210); 3 ♀, on *Dodonaea* sp., Loxton, 30.xi.67 (BMNH; BM 1968-210, 4/78); 3 ♀ (1+2 ♀/slide), ex *Dodonaea attenuata*, Blanchetown, 17.v.1964, HMB (SAM). **Victoria:** 2 ♀, 4 immatures on 1 slide, from *Dodonaea mildura*, C. French No. 89 (BMNH; 1940, 180). **Locality uncertain:** 2 ♀ on one slide, 5 immature ♀, 13 first instar nymphs (7+8/slide), on *Dodonaea bursarifolia*, Murray Bridge, 13. 11. 91, on *Myoporum* sp.

N. S. Wales, Tepper (SAM). **Locality unknown:** 2 ♀, ex dry material in rectangular box #235 (NZAC).

Distribution and host plants

Pulvinaria dodonaeae is an Australian endemic. Specimens have been collected from south-east South Australia, Victoria, northern New South Wales and southern Queensland, and far southern Northern Territory.

Although *P. dodonaeae* is polyphagous all hosts are trees and woody bushes. Known host-plant genera include are *Acacia*, *Ardisia*, *Dodonaea*, *Eremophila* and *Myoporum*, of the arid zone.

Discussion

Pulvinaria dodonaeae is easily distinguished from any other pulvinariine species because it has submarginal chambered ducts of unique structure, J-shaped spiracular setae on each spiracular sclerotisation and numerous tubular ducts on the dorsum. However, the type of tubular ducts and their numerous distribution on the dorsum, and the presence of spiracular sclerotisation in *P. dodonaeae* suggest a relationship with *P. flavicans*, but in *P. flavicans*, the tubular ducts are distributed over dorsum rather than confined to the marginal and submarginal areas, and the spiracular sclerotisation is small, with only 1 spiracular seta per furrow.

Pulvinaria elongata Newstead

(Fig. 5)

Pulvinaria elongata Newstead, 1917, p. 20; Mamet, 1958, p. 74, fig. 2; Williams, 1982, pp. 113-114; Hamon & Williams, 1984, pp. 90-92, figs. 71, 72.

Pulvinaria longisqua De Lotto, 1966, pp. 467-468, fig. 1; Williams, 1982, p. 113 (synonymy).

Saccharipulvinaria longisqua (De Lotto), Tao, Wong & Chang, 1983: 87 (by indication).

Common name: Cottony grass scale (Hamon & Williams, 1984)

Types

Lectotype of *Pulvinaria elongata* (designated by Williams, 1982), ♀, Guyana (BMNH), not examined.

Diagnosis

Appearance: Not seen. Hamon & Williams (1984, p. 90) provided a field description: "Body extremely elongate, convex, cephalic region flattened. Color varies from pale crimson to rosy flesh color with 2 irregular longitudinal lines of brighter crimson. Dry specimens are pale beige. The ovisac is very short, projecting only slightly from beneath the female body."

Slide-mounted adult female: Body length at least twice width; tubular ducts on venter concentrated in submarginal area as a distinct band around entire body.

Description of adult female (13 slide-mounted specimens measured, Fig. 5)


Body (Fig. 5A) elongate oval, 4.6-7.1 (6.2 ± 0.8) mm long, 1.5-2.8 (2.4 ± 0.4) mm wide, length 2.3-3.1 times width. **Anal cleft** 680-1,050 (900 ± 116) μm long, 0.13-0.17 body length.

Margin: *Marginal setae* (Fig. 5B) 15-65 μm long, stout, straight or slightly curved, bluntly pointed; distributed as follows: 79-105 between anterior spiracular furrows, 21-30 between anterior and posterior spiracular furrows on each side, 73-82 between each posterior spiracular furrow and anal cleft. *Spiracular setae* (Fig. 5C) 3 (occasionally with 4 or 5) in each spiracular furrow; median seta 35-60 μm long, 1.8-3.5 times as long as lateral setae, more or less curved, bluntly pointed; lateral setae 10-30 μm long, straight, bluntly pointed. *Spiracular sclerotisation* absent.

Dorsum: *Dorsal setae* (Fig. 5E) 7-10 μm long, lanceolate, scattered.

Submarginal tubercles absent. *Disc pores* not detectable. *Discoidal pores* (Fig. 5G) 4-7 μm in diameter, in group of 15-35 anterior to anal plates. *Tubular ducts* (Fig. 5H)

scattered; duct 8-15 μm long, 2.5 μm wide, inner filament about 10 μm long.

Microducts (Fig. 5I) scattered, about 2 μm long, 1 μm wide, inner filament about 5 μm long. *Anal plates* (Fig. 5J1) each triangular, 135-175 (150 ± 13) μm long, 60-100 (79 ± 12) μm wide; anterolateral margin usually straight, 82-125 (105 ± 16) μm long, posterolateral margin slightly convex, 110-125 (116 ± 6) μm long. Each plate with 3 apical setae 25-30 μm long, 2-3 subapical setae 55-65 μm long, and no inner margin setae. *Ventral thickenings* (Fig. 5J2) elongate triangular. *Fringe setae* 2 pairs, 30-50 μm long. *Anal ring*  60-65 μm long, 55-80 μm wide, with 8 setae 85-190 μm long; translucent pores in 1-2 rows, each pore 5 μm in maximum dimension.

Venter: *Submarginal setae* (Fig. 5L) 12-20 μm long, straight, acute; distributed as follows: 24-37 between anterior spiracular furrows, 7-11 between anterior and posterior spiracular furrows on each side, 22-33 between each posterior spiracular furrow and anal cleft. *Ventral setae* (Fig. 5M) 8-62 μm long, mostly similar to submarginal setae, paired and longer in median areas on each segment. *Interantennal setae* 4-5 (usually 5) pairs, 20-100 μm long. *Prevulvar setae* 3 pairs, 65-80 μm long. *Eyes* not detected in available specimens. *Antennae* (Fig. 5N) well developed, 6-7 (mostly 7) segmented, 377-440 (414 ± 20) μm long, third and fourth segment longest; segment I 50-75 (64 ± 7) μm wide, 50-62 (53 ± 5) μm long. Length of segments II to VII (for 7-segmented specimens): 67-80 (72 ± 4) μm , 75-100 (86 ± 10) μm , 80-107 (97 ± 9) μm , 25-40 (34 ± 6) μm , 15-32 (27 ± 6) μm and 43-50 (47 ± 3) μm , respectively; number of hair-like setae: I, 3-4; II, 1-4; III, 0-4; IV, 1-3; V, 0-3; VI, 0-1; VII, 1-4; number of fleshy setae: V, 1; VI, 1; VII, 2-7. *Clypeolabral shield* 130-150 (139 ± 6) μm long, 120-150 (134 ± 10) μm wide. *Labium* 50-60 (58 ± 5) μm long, 80-100 (91 ± 9) μm wide, with 4 setae 30 μm long on each side. *Legs* (Fig. 5O) well developed, with tibiotarsal sclerotisation but no free articulation; claws without denticle; tarsal digitules slender, knobbed, 62-98 μm long; claw digitules slender, expanded at apex and hammer-like, 35-45 μm long. Leg lengths as follows:

Segments	First leg (μm)	Second leg (μm)	Third leg (μm)
Coxa	80-120 (91 ± 13)	90-130 (108 ± 13)	100-140 (113 ± 14)
Tro.+Fem.	190-220 (206 ± 12)	210-250 (238 ± 15)	215-260 (251 ± 16)
Tibia	140-165 (155 ± 15)	145-210 (171 ± 18)	150-190 (182 ± 21)
Tarsus	90-105 (99 ± 7)	105-130 (119 ± 7)	110-130 (124 ± 7)
Claw	25-35 (30 ± 3)	25-38 (34 ± 3)	30-40 (35 ± 3)
Total	525-670 (583 ± 42)	580-758 (669 ± 50)	620-810 (704 ± 55)

Anterior spiracles (Fig. 5P) each 65-80 (74 ± 6) μm long, 45-75 (53 ± 10) μm wide across atrium, atrium wider than apodeme. *Posterior spiracles* similar to anterior ones, each 90-112 (99 ± 8) μm long, 60-72 (65 ± 5) μm wide across atrium. *Spiracular pore bands* each 1-5 (mostly 2-3) pores wide, reaching apodemal base of spiracles or a few pores beyond. *Spiracular pores* (Fig. 5Q) quinquelocular, 5-6 μm in diameter, 30-44 in anterior spiracular pore band, 33-52 in posterior spiracular pore band. *Multilocular pores* (Fig. 5R) 5-8 μm in diameter, 6-9 loculi, around anal area, in transverse bands on abdomen, occasionally, 1-2 multilocular pores between antennal base and mouthparts. *Tubular ducts* numerous in submarginal area and forming a distinct band around entire body, few scattered in other parts; of 2 types: first (Fig. 5S1) with slender knobbed inner filament (less than 20% in band), duct 8-10 μm long, 3 μm wide, inner filament 8-10 μm long; second with flowery tipped inner filament, of 2 sizes: small size (Fig. S2) (more than 20% in band) with duct 13-17 μm long, 2-2.5 μm wide, inner filament about 16 μm long, 1.5 μm wide, flowery apex 5 μm wide; large size (Fig. S3) (more than 60%) with duct 17-30 μm long, 3-4 μm wide, inner filament 20-25 μm long, 3-5 μm wide, flowery apex 5-8 μm wide. *Microducts* (Fig. 5T) evenly scattered, 4-5 μm long, 1.5 μm wide.

Material examined

Queensland: 3 ♀, on *Saccharum officinarum*, intercepted at Brisbane, 7.ii.1968, A.R. Brimblecombe (BMNH, 1968. 27; C.I.E. 9486. A2270); 8 ♀ (1 ♀/slide except one

slide with 2 ♀, another with 3 ♀), on sugar-cane, Eight Mile Plains, 18.vii.1969, A.R. Brimblecombe (BMNH; C.I.E. A3486); 3 ♀ (1 ♀ + 2 ♀/slide), on sugar-cane, Eight Mile Pls, 18. vii.1969 (BMNH; C.I.E. 11892 B63, A3544).

Distribution and host plants

Pulvinaria elongata is an introduced species in Australia and only recorded from Queensland. Williams (1982, p. 114) pointed out that "Wilson (1959) mentioned this species under the name *P. iceryi* from the quarantine plot at Magnetic I., Queensland, Australia, on sugar-cane introduced from New Guinea. There is, however, still no definite record from Papua New Guinea." It is widely distributed in other tropical countries: Bahamas, Barbados, Cameroon, Dominican Republic, Guyana, Kenya, Mexico, Morocco, Nigeria, Puerto Rico, St Kitts, Trinidad, United States of America and Venezuela (Williams, 1982).

The main host plant is sugarcane but it also is recorded on rice and *Andropogon gayanus* in Nigeria (Williams, 1982)

Discussion

It is very easy to separate this introduced species from other species in Australia. *Pulvinaria elongata* has an elongate body shape, the ventral tubular ducts are distributed as a distinct submarginal band, the dorsal setae are lanceolate and the host plant is sugar-cane.

Pulvinaria elongata belongs to the group of species, including *P. iceryi* (Signoret), *P. saccharia* De Lotto, *P. sorghicola* De Lotto and *P. tenuivalvata* (Newstead), which feed on sugar-cane and other grasses (Williams, 1982). Williams (1982, p. 113) provided a key to each of the above species. In the key, *P. elongata* was included in couplet 2 as having the dorsum without tubular ducts. However, dorsal tubular ducts are found in Australian specimens of *P. elongata*, which therefore key to *P. sorghicola* described from South Africa. But in Australian specimens of *P. elongata*, dorsal tubular ducts are rare, in contrast to the numerous ducts found in *P. sorghicola*.

Also the submarginal tubular duct band of *P. elongata* has ducts distributed consistently dense, whereas in *P. sorghicola* tubular ducts tend to be progressively fewer toward the anterior extremity of the body. Moreover, in *P. sorghicola* no "ovisac, or trace of it was seen." (De Lotto, 1979, p. 252).

Tao *et al.* (1983) established a genus *Saccharipulvinaria* to include *P. iceryi*, and suggested that *P. longisqua* De Lotto [= *P. elongata*] might be transferred to this genus. The characters that Tao *et al.* mentioned to separate *Saccharipulvinaria* from *Pulvinaria* are: tubular ducts present on ventral submarginal area, spiracular furrow shallow and claw digitules same shape as tarsal digitules. As early as 1964, De Lotto stated that a new genus may be required for this group when a thorough revision of *Pulvinaria* is undertaken. Williams (1982) mentioned that it was not clear which characters could be used to separate this group of species from the large number of species already assigned to *Pulvinaria*. Whether or not the features that Tao *et al.* used to distinguish *Saccharipulvinaria* from *Pulvinaria* are reliable or sufficient to warrant generic distinction is still unknown. A worldwide revision and a phylogenetic study of the Pulvinariini have not been done and knowledge of the first instar nymphs and adult males of the cottony soft scales remains poor.

Pulvinaria flavicans Maskell

(Figs 2C, D, G & H; 6)

Pulvinaria flavicans Maskell, 1889, pp. 103-104, pl. xii Fig. 5 3; Cockerell, 1899a, p. 272; Fernald, 1903, p. 132; Froggatt, 1915, pp. 414-415; 1921, p. 8.

Pulvinaria tecta Maskell, 1894, p. 79, pl. iv figs 9-14 (in part [buff variety]); 1896, p. 393 (white variety, misidentification of *Callococcus acaciae* (Maskell)); Cockerell, 1896b, p. 49; Fernald, 1903, p. 139 (in part); Froggatt, 1915, p. 413, pl. x fig 2 (misidentification of *Callococcus acaciae*); 1921, p. 13, fig. 7 (misidentification of *Callococcus acaciae*). **New Synonymy**

Pulvinaria contexta Froggatt, 1915, p. 413; 1921, p. 7. **New Synonymy**

Suggested common name: Yellow cottony soft scale

Types

Lectotype of *Pulvinaria flavicans* (present designation): ♀, Australia, ex dry material in cylindrical box, labelled: "*Pulvinaria, flavicans*, ♀" (ANIC from NZAC).

Paralectotypes (present designation): 1 ♀, same data as lectotype (NZAC); Additional dry material (3 ♀) in cylindrical box, same data as lectotype (NZAC).

Maskell's type material has no type locality or host plant. The original description (Maskell, 1889) only mentioned that the specimens are from South Australia.

Lectotype of *Pulvinaria tecta* (present designation): ♀, Australia, labelled: "*Pulvinaria, tecta*, adult female, 1893 W. M. M" (ANIC from NZAC; Maskell's original slide). **Paralectotypes** (present designation): 2 ♀, 1 anterior part of adult ♀, 3 first instar nymphs on one slide, same data as lectotype (NZAC; Maskell's original slides); 2 ♀, ex dry material in cylindrical box, label on lid: "*Pulvinaria, tecta*, buff form, Australia" (NZAC; Maskell's original material); Additional dry material in cylindrical box, same data as above (NZAC).

Maskell's material for *P. tecta* is a mixture of two species. All specimens on the original slides are identical. For the dry material in two cylindrical boxes, one labelled 'buff form' and the other labelled 'white form'. Only the adult females mounted from 'buff form' match the original slides, while the 'white form' is a different species (Asterolecaniidae: *Callococcus acaciae*). Maskell's description of the appearance of the females seems to include the white form. However, the description of adult female seems to be based on the 'buff form' only, although Maskell mentioned that his specimens were from three people.

The collection localities specified by Maskell (1894) are Sydney and Melbourne. The host plants Maskell (1894) mentioned are orange, *Acacia* sp. and *Daviesia corymbosa*. It is uncertain which locality and host plant pertain to type specimens because there is nothing else on the original slides except the species name.

Lectotype of *Pulvinaria contexta* (present designation): ♀, Australia, ex dry stem, 2 labels: "293 (1899), Mittagong" and "*P. contexta* Froggatt, Mittagong, N.S.W." (BCRI). **Paralectotype** (present designation): 2 ♀, ex tray, 2 labels: "293 (1899), Mittagong" and "*Pulvinaria contexta* Green [sic]" (QM); 1 ♀, remounted from Froggatt's original slide labelled: "*Pulvinaria, contexta*, n. sp." [Froggatt's handwriting] (BCRI).

Froggatt (1915) mentioned that the host plants of *P. contexta* are *Bossiaea* sp. and *Dillwynia juniperina*.

Diagnosis

Appearance: Adult female shrivelled, dark-brown, usually hidden^d by ovisac; body about 5.0 mm long, 3.0 mm wide. Ovisac white, about 4.2 mm long, 4.4 mm wide, convex, usually surrounding most of body.

Slide-mounted adult female: Body shape pear-like, anterior part slightly contracted, posterior part broader; tibiotarsal sclerotisation and free articulation absent; a small narrow usually triangular spiracular sclerotisation and only 1 spiracular seta present in each spiracular furrow; 1 subapical seta in each anal plate; multilocular pores oval, lateral loculi not visible, middle loculus well developed.

Description of adult female (15 slide-mounted specimens measured, Fig. 6)

Body (Fig. 6A) oval, usually pear-like, posterior part broader, 3.6-6.8 (5.3 ± 1) mm long, 2.1-3.6 (3.1 ± 0.7) mm wide, length 1.3-2.3 times width. Dorsum convex and larger than venter. **Anal cleft** 550-800 (632 ± 84) μ m long, 0.09-0.16 body length.

Margin: Marginal setae (Fig. 6B) 19-42 μ m long, stout, straight; distributed as follows: 27-49 between anterior spiracular furrows, 8-18 between anterior and posterior spiracular furrows on each side, 30-39 between each posterior spiracular furrow and anal cleft. **Spiracular setae** (Fig. 6C) 1 (occasionally 2) in each spiracular furrow, 30-55 μ m long, stout, straight or slightly curved, bluntly tipped. **Spiracular sclerotisation** (Fig. 6C) present, small and triangular.

Dorsum: *Dorsal setae* (Fig. 6E) 6-10 μm long, spine-like, scattered.

Submarginal tubercles absent. *Disc pores* (Fig. 6G) 3-4 μm in diameter, scattered.

Discoideal pores absent. *Tubular ducts* (Fig. 6H) with flowery tipped inner filament, numerous over dorsum except absent in most of median area; duct 13-25 μm long, 3-4 μm wide, inner filament 7-18 μm long, 1.5-2 μm wide, flowery apex about 3 μm wide.

Microducts not detectable. *Anal plates* (Fig. 6J1) each triangular, lateral angle more rounded, 145-177 (162 ± 11) μm long, 48-80 (69 ± 9) μm wide, anterolateral margin straight or slightly convex, 75-100 (89 ± 7) μm long; posterolateral margin slightly concave, 90-115 (108 ± 8) long. Each plate with 3 apical setae 18-35 μm long, 1 inner margin seta 16-32 μm long; 1 subapical seta 15-25 μm long. *Ventral thickenings* (Fig. J2) triangular. *Fringe setae* 2 pairs, 20-40 μm long. *Anal ring* (Fig. 6K) subcircular, 50-65 (61 ± 5) μm long, 55-72 (62 ± 5) μm wide; with 8 setae 140-250 μm long; translucent pores in 1-3 rows, each pore 4-5 μm in maximum dimension.

Venter: *Submarginal setae* (Fig. 6L) 7-20 μm long, slender, usually straight; distributed as follows: 12-16 between anterior spiracular furrows, 5-7 between anterior and posterior spiracular furrows on each side, 12-18 between each posterior spiracular furrow and anal cleft. *Ventral setae* (Fig. 6M) 7-30 μm long, similar to submarginal setae, clustered around anal region, rare in other parts. *Interantennal setae* 2 pairs, 20-55 μm long, close to base of each antenna. *Prevulvar setae* 3-4 pairs, 25-80 μm long, posterior pair longest. *Eyes* not visible. *Antennae* (Fig. 6N) well developed, 7-9 (mostly 8) segmented, 271-328 (300 ± 19) μm long, usually third (occasionally fourth) segment longest; segment I 42-60 (50 ± 5) μm wide, 35-50 (42 ± 7) μm long; length of segments II to VIII (for 8-segmented specimens): 27-42 (37 ± 4) μm , 35-55 (46 ± 5) μm , 30-50 (40 ± 6) μm , 18-40 (26 ± 4) μm , 20-35 (26 ± 4) μm , 23-45 (28 ± 7) μm and 23-50 (43 ± 6) μm , respectively; number of hair-like setae: I, 2-3; II, 2; III, 0; IV, 0; V, 2-3; VI, 1; VII, 1-3 and VIII, 2-4; number of fleshy setae: VI, 1; VII, 1-2 and VIII, 4-6. *Clypeolabral shield* 150-170 (159 ± 8) μm long, 135-170 (148 ± 11) μm wide. *Labium* 55-85 (74 ± 9) μm long, 75-150 (106 ± 24) μm wide, with 4 setae 15-25 μm long on each side. *Legs* (Fig. 6O) well developed, but small compared to body size; tibiotarsal

Dorsum: *Dorsal setae* (Fig. 6E) 6-10 μm long, spine-like, scattered.

Submarginal tubercles absent. *Disc pores* (Fig. 6G) 3-4 μm in diameter, scattered.

Discoideal pores absent. *Tubular ducts* (Fig. 6H) with flowery tipped inner filament, numerous over dorsum except absent in most of median area; duct 13-25 μm long, 3-4 μm wide, inner filament 7-18 μm long, 1.5-2 μm wide, flowery apex about 3 μm wide.

Microducts not detectable. *Anal plates* (Fig. 6J1) each triangular, lateral angle more rounded, 145-177 (162 ± 11) μm long, 48-80 (69 ± 9) μm wide, anterolateral margin straight or slightly convex, 75-100 (89 ± 7) μm long; posterolateral margin slightly concave, 90-115 (108 ± 8) long. Each plate with 3 apical setae 18-35 μm long, 1 inner margin seta 16-32 μm long; 1 subapical seta 15-25 μm long. *Ventral thickenings* (Fig. J2) triangular. *Fringe setae* 2 pairs, 20-40 μm long. *Anal ring* (Fig. 6K) subcircular, 50-65 (61 ± 5) μm long, 55-72 (62 ± 5) μm wide; with 8 setae 140-250 μm long; translucent pores in 1-3 rows, each pore 4-5 μm in maximum dimension.

Venter: *Submarginal setae* (Fig. 6L) 7-20 μm long, slender, usually straight; distributed as follows: 12-16 between anterior spiracular furrows, 5-7 between anterior and posterior spiracular furrows on each side, 12-18 between each posterior spiracular furrow and anal cleft. *Ventral setae* (Fig. 6M) 7-30 μm long, similar to submarginal setae, clustered around anal region, rare in other parts. *Interantennal setae* 2 pairs, 20-55 μm long, close to base of each antenna. *Prevulvar setae* 3-4 pairs, 25-80 μm long, posterior pair longest. *Eyes* not visible. *Antennae* (Fig. 6N) well developed, 7-9 (mostly 8) segmented, 271-328 (300 ± 19) μm long, usually third (occasionally fourth) segment longest; segment I 42-60 (50 ± 5) μm wide, 35-50 (42 ± 7) μm long; length of segments II to VIII (for 8-segmented specimens): 27-42 (37 ± 4) μm , 35-55 (46 ± 5) μm , 30-50 (40 ± 6) μm , 18-40 (26 ± 4) μm , 20-35 (26 ± 4) μm , 23-45 (28 ± 7) μm and 23-50 (43 ± 6) μm , respectively; number of hair-like setae: I, 2-3; II, 2; III, 0; IV, 0; V, 2-3; VI, 1; VII, 1-3 and VIII, 2-4; number of fleshy setae: VI, 1; VII, 1-2 and VIII, 4-6. *Clypeolabral shield* 150-170 (159 ± 8) μm long, 135-170 (148 ± 11) μm wide. *Labium* 55-85 (74 ± 9) μm long, 75-150 (106 ± 24) μm wide, with 4 setae 15-25 μm long on each side. *Legs* (Fig. 6O) well developed, but small compared to body size; tibiotarsal

sclerotisation and free articulation absent; claws with denticle near tip; tarsal digitules slender, knobbed, 40-57 μm long; claw digitules slender, slightly expanded at apex, 25-35 μm long. Leg lengths as follows:

Segments	First leg (μm)	Second leg (μm)	Third leg (μm)
Coxa	78-95 (85 ± 7)	80-100 (86 ± 6)	87-100 (94 ± 5)
Tro.+Fem.	168-199 (182 ± 10)	180-222 (196 ± 14)	190-235 (209 ± 15)
Tibia	100-125 (109 ± 9)	117-133 (125 ± 7)	122-140 (129 ± 7)
Tarsus	85-102 (92 ± 7)	100-115 (109 ± 4)	100-125 (115 ± 9)
Claw	20-25 (22 ± 2)	22-28 (24 ± 2)	23-25 (25 ± 1)
Total	450-538 (490 ± 30)	509-591 (542 ± 30)	535-615 (542 ± 30)

Anterior spiracles (Fig. 6 P) each 45-75 (61 ± 11) μm long, 48-60 (53 ± 4) μm wide across atrium, atrium slightly wider than apodeme. *Posterior spiracles* similar to anterior ones, each 62-85 (70 ± 8) μm long, 52-72 (66 ± 6) wide across atrium. *Spiracular pore bands* each 1-2 pores wide, reaching atrium only. *Spiracular pores* (Fig. 6Q) quinquelocular, 4-5 μm in diameter, 30-44 in anterior spiracular pore band, 29-48 in posterior spiracular pore band. *Multilocular pores* (Figs 2C-D, 6R) oval, 7-8 μm long, 5-6 μm wide, lateral loculi not visible, central loculus well developed; distributed around anal area, in transverse bands on abdomen, in group beside each second and third coxa, and a few in posterior part of prothorax anterior to second coxa. *Tubular ducts* (Fig. 6S) with flowery tipped inner filament, numerous in submarginal area, a few scattered in median and submedian area of body, but lacking on head and in median and submedian area of prothorax; duct 15-25 μm long, 3-4 μm wide, inner filament 7-15 μm long, 2-3 μm wide, flowery apex 4 μm wide. *Microducts* (Figs 2G, H, 6T) scattered, dumb-bell shaped, 4-6 μm long, 2 μm wide.

Other material examined

Australian Capital Territory: 1 ♀, on unidentified bushpea, Black Mt, Canberra, 7.xii.1971, J.W. Beardsley ACT-233 (ANIC); 5 ♀ on four slides, on *Bossiaea*

buxifolia, Black Mt, Canberra, 13.xi.1953, (BMNH, BM-1958-578; A/513478). **New South Wales:** 2 ♀, on *Oxylobium* sp., Bankstown, 10.xi.1929 (BCRI; 18/8); 5 ♀ on one slide, from *Acacia longifolia*, W.W. Froggatt no. 442 (BMNH); 6 ♀ (5 + 1 ♀/slide), on *Dillwynia juniperina*, W.W. Froggatt no. 351 (BMNH); 4 ♀ (2 ♀/slide), on *Daviesia corymbosa*, Faulconbridge, 29.ix.1969, H.J. Banks (BMNH; BM 1971.1; CIE A3931). **South Australia:** 7 ♀ (2 or 3 ♀/slide), on *Templetonia retusa*, Innes Cons. Pk, 12.x.1974, D.E. Symon (ANIC; WARI No. 12/74); 12 ♀ (1 or 2 ♀/slide), 15 first instar nymphs (7+8/slide), on *Templetonia retusa*, Stenhouse Bay, i.1975, D.E. Symon (ANIC; WARI No. 1/75); 3 ♀, ex spirit material in vial, Yorke Peninsula, near salt lakes, Innes National Pk, 6.xi.1976, I.C. Kowanko (SAM). **Victoria:** 3 ♀ on one slide, on *Acacia* sp., Kiata, C.French no. 215 (BMNH). **Locality unknown:** 2 ♀, ex dry material in rectangular box #54" (NZAC). 2 ♀, ex dry material in rectangular box #288" (NZAC).

Distribution and host plants

This is an endemic Australian species and has been recorded from south-east South Australia, Southern Victoria, the Australian Capital Territory and south-east New South Wales.

Pulvinaria flavicans is found on a wide variety of native peas and occasionally on wattles. Known host-plant genera are *Acacia*, *Bossiaea*, *Daviesia*, *Dillwynia*, *Oxylobium* and *Templetonia*.

Discussion

Pulvinaria flavicans is a peculiar species. It has no tibiotarsal sclerotisation, which is unusual for the genus, and the multilocular pores are of unique structure. Moreover, *P. flavicans* has only 1 spiracular seta. The ovisac is also different in appearance from that of other *Pulvinaria* species. The distribution of tubular ducts and the shape of the claw digitules of *P. flavicans* are similar to those of *P. salicorniae*, but

these two species are very different in other characters. Similarities between *P. flavicans* and *P. dodonaeae* have been discussed under *P. dodonaeae*.

***Pulvinaria floccifera* (Westwood)**

(Fig. 7)

Coccus flocciferus Westwood, 1870, p. 308, pl. 52.

Pulvinaria camillicola Signoret, 1873, p. 32, pl. 2 fig. 4, 6; Maskell, 1879, p. 207;
Green, 1897, p. 73 (synonymy).

Pulvinaria brassiae Cockerell, 1895, p. 135; 1900, p. 596 (synonymy by indication).

Pulvinaria floccifera (Westwood), Green, 1897, pp. 72, 73; Cockerell, 1900, p. 596;
Fernald, 1903, p. 132; Froggatt, 1915, p. 415; 1921, p. 9; Steinweden, 1946,
p. 6, fig. 4; Ezzat & Hussein, 1969, p. 417, fig. 22; Williams & Kosztarab,
1972, p. 135-141, pl. 19, photo 33; Hamon & Williams, 1984, p. 96-98, fig.
75; Gill, 1988, p. 87, fig. 36.

Pulvinaria theae Froggatt, 1915, p. 418, pl x fig. 3; 1921, p. 14, fig. 8. New

Synonymy

Chloropulvinaria floccifera (Westwood), Borchsenius, 1952a, p. 300; 1957, p. 205-
210, figs. 190, 191; Khadzhibeili, 1978, p. 546; Tereznikova, 1981, p. 132,
fig. 110, 111; Wang, 1982, p. 34-36, fig. 12; Young, 1982, p. 158;
Kosztarab & Kozár, 1988, p. 177, fig. 83.

Common name: Cottony camellia scale (Gill, 1988)

Types

Types of *Coccus flocciferus* not examined.

Lectotype of *Pulvinaria theae* (present designation), ♀ (encircled in black on slide), New South Wales, labelled: "*Pulvinaria, theae*, Frogg., from Tea plant, Australia. Coll. W.W. Froggatt, no 434 (BMNH). **Paralectotypes** (present designation): 3 ♀, on same slide as lectotype (BMNH).

The type material of *Pulvinaria theae* in BCRI is only represented by ovisacs and all the insects have fallen off and had been lost. However, the specimens in BMNH have exactly the same data and collection number as the type material in BCRI, and therefore are considered as part of the type series. The lectotype and paralectotypes designated above have been chosen from the BMNH specimens.

Froggatt (1915, p. 418) recorded that *P. theae* was "Found upon the foliage of a tea plant (*Thea viridis*) growing in a garden at Richmond, New South Wales (Mr. C.T. Musson)."

Diagnosis

Appearance: Adult female usually becomes detached from ovisac, not seen in dry material examined. Gill (1988, p. 87) stated: "Adult females 2 to 5 mm long, oval, fairly flat." Ovisac white, 6.0-8.0 mm long, 2.0-3.0 mm wide, slightly convex, with 3 shallowly longitudinal furrows.

Slide-mounted adult female: Submarginal tubercles present; marginal setae slender and bifid or fimbriate; no subdiscal setae; no cell-like clear areas on dorsum; subapical setae 2 pairs.

Description of adult female (14 slide-mounted specimens measured, Fig. 7)

Body (Fig. 7A) oval to broadly oval, 3.1-4.7 (3.07 ± 0.4) mm long, 2.1-3.2 (2.6 ± 0.4) mm wide, length, 1.2-1.7 times width. **Anal cleft** 360-630 μ m long, 0.11-0.16 body length.

Margin: *Marginal setae* (Fig. 7B) 30-90 μ m long, slender, straight or curved, some pointed, some bifid or fimbriate; distributed as follows: 55-88 between anterior spiracular furrows, 17-25 between anterior and posterior spiracular furrows on each side, 51-63 between each posterior spiracular furrow and anal cleft. *Spiracular setae* (Fig. 7C) 3 in each spiracular furrow; median seta 60-88 μ m long, 2.0-4.0 times as long as lateral setae, strong, straight or slightly curved, bluntly pointed; lateral setae 20-38 μ m long, straight, bluntly pointed. *Spiracular sclerotisation* absent.

Dorsum: *Dorsal setae* (Fig. 7E) 6-8 μm long, spine-like, scattered. *Submarginal tubercles* (Fig. 7F) 7-9 around body, each 8-11 μm in diameter, 8-10 μm in deep. *Disc pores* (Fig. 7G1) about 3 μm in diameter, scattered. *Discoideal pores* (Fig. 7G2) 4-5 μm in diameter, in group of 10-30 in median area anterior to anal plates. *Tubular ducts* (Fig. 7H) sparsely scattered, duct 4-5 μm long, 3 μm wide, inner filament 3-4 μm long. *Microducts* (Fig. 7I) scattered, 2 μm long, 1 μm wide, inner filament 6-7 μm long. *Anal plates* (Fig. 7J1) each triangular, 143-170 (151 ± 10) μm long, 65-100 (73 ± 11) μm wide; anterolateral margin slightly concave, 80-125 (95 ± 13) μm long, posterolateral margin convex, 95-130 (108 ± 10) μm long. Each plate with 4 apical setae 18-30 μm long, 2 subapical setae 30-55 μm long, and no inner margin setae. *Ventral thickenings* (Fig. 7J2) elongate triangular. *Fringe setae* 2 pairs, 38-65 μm long. *Anal ring* 60-90 (7 ± 12) μm wide (length not measured due to orientation), with 8 (1 specimen with 10) setae 70-250 μm long; translucent pores in 2 rows, each pore 5-6 μm in maximum dimension.

Venter: *Submarginal setae* (Fig. 7L) 13-20 μm long, slender, straight, acute; distributed as follows: 15-30 between anterior spiracular furrows, 5-11 between anterior and posterior spiracular furrows on each side, 18-29 between each posterior spiracular furrow and anal cleft. *Ventral setae* (Fig. 7M) 10-20 μm long, mostly similar to submarginal setae, setae paired and longer (28-100 μm) in median area of each segment. *Interantennal setae* 5-8 pairs, 13-190 μm long. *Prevulvar setae* 3 pairs, 110-225 μm long. *Eyes* not seen. *Antennae* (Fig. 7N) well developed, 8 (1 specimen with only 6) segmented, 373-532 (425 ± 49) μm long, third segment longest; segment I 50-85 (72 ± 15) μm wide, 30-65 (43 ± 12) μm long. Length of segment II to VIII: 50-85 (68 ± 10) μm , 55-100 (74 ± 13) μm , 50-87 (63 ± 11) μm , 40-60 (53 ± 6) μm , 30-40 (34 ± 5) μm , 30-40 (33 ± 4) μm and 58-85 (63 ± 8) μm , respectively; number of hair-like setae: I, 3; II, 2; III, 0-1; IV, 0-1; V, 2-3; VI, 0; VII, 1; VIII, 2-3; number of fleshy setae: VI, 1; VII, 1; VIII, 5-8. *Clypeolabral shield* 140-170 (154 ± 9) μm long, 130-170 (152 ± 11) μm wide. *Labium* 55-70 (68 ± 5) μm long, 90-120 (105 ± 12) μm wide, with 4 setae 18-25 μm long on each side. *Legs* (Fig. 7O) well developed, with tibiotarsal sclerotisation and free

articulation; claws without denticle; tarsal digitules slender, knobbed, 50-75 μm long; claw digitules broad, equal, expanded at apex, 35-45 μm long. Leg lengths as follows:

Segments	First leg (μm)	Second leg (μm)	Third leg (μm)
Coxa	75-130(100 \pm 15)	90-140(112 \pm 15)	90-150(116 \pm 16)
Tro.+Fem.	210-320(262 \pm 34)	240-345(282 \pm 37)	245-350(289 \pm 34)
Tibia	160-250(206 \pm 25)	190-270(227 \pm 26)	190-260(228 \pm 22)
Tarsus	80-110(96 \pm 8)	90-120(102 \pm 9)	95-120(104 \pm 7)
Claw	27-38(30 \pm 3)	25-40(31 \pm 4)	30-35(31 \pm 2)
Total	552-848(693 \pm 83)	640-915(754 \pm 82)	650-915(768 \pm 79)

Anterior spiracles (Fig. 7P) each 55-90 (69 \pm 12) μm long, 30-55 (42 \pm 8) μm wide across atrium, atrium ^hslightly wider or more narrow than apodeme. *Posterior spiracles* similar to anterior ones, each 65-90 (77 \pm 10) μm long, 38-65 wide across atrium. *Spiracular pore bands* each 1-3 pores wide, extending beyond apodemal base of spiracles. *Spiracular pores* (Fig. 7Q) quinquelocular except some pores with 4 loculi only, 4-5 μm in diameter, 41-80 in anterior spiracular pore band, 50-91 in posterior spiracular pore band. *Multilocular pores* (Fig. 7R) 5-7 μm in diameter, 5-10 loculi, around anal area, in transverse bands on abdomen and a few beside hind coxa. *Tubular ducts* of 2 types: first (Fig. 7S1) with slender, knobbed inner filament, numerous in posterior to posterior spiracular pore band of submarginal areas, scattered in submarginal area from posterior spiracular pore bands to antennal level, lacking in head, duct 6-15 μm long, 3 μm wide, inner filament 10-13 μm long; second (Fig. 7S2, S3) with flowery tipped inner filament, inner filaments of 2 thicknesses: one (Fig. 7 S2) with slender filament, distributed in submarginal area of meso- and metothorax and abdomen, and in median and submedian areas of posterior two abdominal segments, duct 10-15 μm long, 3-4 μm wide, inner filament 10-15 μm long, 0.5 μm wide, flowery apex 4-5 μm wide; another (Fig. 7S3) with broader inner filament, scattered in median and submedian areas; duct 13-20 μm long, 3-4 μm wide, inner filament 15-22 μm long, 3 μm wide, flowery apex 4-5 μm wide.

Microducts (Fig. 7T) scattered, but numerous in submarginal area, 3-4 μm long, 2 μm wide.

Other material examined

New South Wales: 1 ♀, ex *Camellia japonica*, Beecroft, Sydney, xii.1982, Judy McMaugh (ANIC). **South Australia:** 5 ♀ (1+4/slide), ex leaves of *Camellia*, Tea Tree Gully, 22.xi.1965 (ANIC; WARI No. 58/65). **Victoria:** 2 ♀ on one slide, on *Camellia*, Burnley Gardens, xi.1966, L.D.Crawford (ANIC). **Locality unknown:** 2 ♀ (MVM).

Distribution and host plants

In Australia, specimens of *P. floccifera* are known from places where camellia is planted as an ornamental, including Sydney, Melbourne and Adelaide. Outside Australia it is known from China, Costa Rica, Europe, India, Japan, New Zealand, Trinidad and United States of America (Hamon & Williams, 1984).

Although this species is restricted to *Camellia* in Australia, it is polyphagous elsewhere (Kosztarab & Kozár, 1988).

Discussion

Pulvinaria floccifera is the type species of Borchsenius' (1952) genus *Chloropulvinaria* which is characterised by having bifid, branched, toothed or fimbriate marginal setae. This group of insects is represented in Australia by *P. decorata*, *P. hydrangeae*, *P. polygonata*, *P. psidii* and *P. sp. n.* as well as *P. floccifera*. *Pulvinaria floccifera* can be separated from other species of the group by the following combination of characters: the presence of submarginal tubercles and two subapical setae and the absence of cell-like clear areas on the dorsum and without subdiscal setae on the anal plates.

Pulvinaria hydrangeae Steinweden

(Fig. 8)

Pulvinaria hydrangeae Steinweden, 1946, p. 7, fig. 5; Takahashi, 1955, p. 149; 1956, p. 24; Borchsenius, 1957, p. 252; Brookes, 1964, p. 17; Williams & Kosztarab, 1972, pp. 141-145, pl. 20; Hamon & Williams, 1984, pp. 98-100, fig. 76; Gill, 1988, p. 88, fig. 37.

Eupulvinaria hydrangeae (Steinweden), Canard, 1965, p. 170; 1965b, p. 424; 1969, pp. 457-460, figs. 1, 2.

Common name: Cottony hydrangea scale (Gill, 1988)

Types

Not examined

Diagnosis

Appearance: Not seen. Gill (1988, p. 88) stated: "Adult females 3 to 5 mm long, ovoid to circular, fairly flat." and "Ovisac white, broadly and shallowly grooved, convex, about 10 mm long."

Slide-mounted adult female: Subdiscal seta present; submarginal tubercles absent; tubular ducts numerous all over venter; multilocular pores each with a slit in central loculus.

Description of adult female (14 slide-mounted specimens measured, Fig. 8)

Body (Fig. 8A) oval to broadly oval, 2.5-4.6 (3.5 ± 0.7) mm long, 2.1-3.9 (3.0 ± 0.6) mm wide, length 1.1-1.4 times width. *Anal cleft* 250-500 (377 ± 76) μ m long, 0.09-0.12 body length.

Margin: Marginal setae (Fig. 8B) 28-75 μ m long, slender, straight or curved, acute or occasionally bifid or fimbriate; distributed as follows: 39-55 between anterior spiracular furrows, 12-25 between anterior and posterior spiracular furrows on each side,

33-54 between each posterior spiracular furrow and anal cleft. *Spiracular setae* (Fig. 8C) 3 (except one with 4) in each spiracular furrow; median seta 70-90 μm long, 1.1-3.2 times as long as lateral setae, curved, bluntly pointed or round at tip; lateral setae 28-80 μm long, curved, bluntly pointed, some expanded and curved near tip. *Spiracular sclerotisation* absent.

Dorsum: *Dorsal setae* (Fig. 8E) 7-10 μm long, spine-like, scattered.

Submarginal tubercles absent. *Disc pores* not detectable. *Discoideal pores* (Fig. 8G) 3-4 μm in diameter, in group of 17-64 in median area anterior to anal plates. *Tubular ducts* (Fig. 8H) sparsely scattered, duct 7-10 μm long, 3-4 μm wide, inner filament 7-10 μm long. *Microducts* (Fig. 8I) scattered, 2 μm long, 1 μm wide, inner filament 6 μm long. *Anal plates* (Fig. 8J1) each triangular, 140-160 (149 ± 6) μm long, 70-95 (79 ± 8) μm wide; anterolateral margin slightly concave, 95-115 (118 ± 5) μm long, posterolateral margin convex, 11-125 (118 ± 5) μm long. Each plate with 3 apical setae 18-32 μm long and 1 subdiscal seta 15-32 μm long, 2 (occasionally 3) subapical setae 40-70 μm long, and no inner margin setae. *Ventral thickenings* (Fig. 8J2) elongate triangular. *Fringe setae* 2-3 pairs, 20-80 μm long. *Anal ring* 80 μm long, 67-82 μm wide, with 8 setae: 2 small 100 μm long, others 130-290 μm long; translucent pores in 2 rows, each pore oval, 4-7 μm in maximum dimension.

Venter: *Submarginal setae* (Fig. 8L) 18-25 μm long, slender, straight or slightly curved, tapering; distributed as follows: 16-24 between anterior spiracular furrows, 4-9 between anterior and posterior spiracular furrows on each side, 16-25 between each posterior spiracular furrow and anal cleft. *Ventral setae* (Fig. 8M) 13-25 μm long, similar to submarginal setae, setae paired and longer (70-140 μm) in median area on each segment. *Interantennal setae* 4-7 pairs, 20-210 μm long. *Prevulvar setae* 3 pairs, 85-180 μm long. *Eyes* detectable in some specimens, oval, 18-23 μm in maximum dimension. *Antennae* (Fig. 8N) well developed, 8 (1 specimen with 7) segmented, 412-510 (470 ± 30) μm long, third segment longest; segment I 70-90 (76 ± 6) μm wide, 50-70 (59 ± 8) μm long. Length of segments II to VIII: 60-80 (72 ± 6) μm , 90-115 (107 ± 7) μm , 60-80 (73 ± 6) μm , 50-60 (54 ± 5) μm , 30-40 (37 ± 4) μm , 25-35 (31 ± 4) μm and 35-55

(47 ± 6) μm , respectively; number of hair-like setae: I, 2-3; II, 2; III, 0; IV, 0; V, 1-3 (mostly 2); VI, 0; VII, 0-1; VIII, 3-6; number of fleshy setae: VI, 1; VII, 1; VIII, 2-4. *Clypeolabral shield* 170-200 (188 ± 12) μm long, 170-200 (187 ± 11) μm wide.

Labium 70-115 (79 ± 16) μm long, 110-150 (129 ± 13) μm wide, with 4 setae 20-30 μm long on each side. *Legs* (Fig. 8O) well developed, with tibiotarsal sclerotisation and free articulation; claws without denticle; tarsal digitules slender, knobbed, 70-82 μm long; claw digitules broad, equal, expanded at apex, 40-55 μm long. Leg lengths as follows:

Segments	First leg (μm)	Second leg (μm)	Third leg (μm)
Coxa	110-140 (125 ± 9)	120-150 (135 ± 11)	130-180 (141 ± 15)
Tro.+Fem.	290-340 (313 ± 16)	320-370 (344 ± 20)	310-380 (345 ± 20)
Tibia	200-250 (218 ± 14)	210-240 (226 ± 10)	210-230 (223 ± 8)
Tarsus	90-120 (104 ± 8)	95-115 (106 ± 6)	100-115 (107 ± 6)
Claw	32-38 (35 ± 2)	35-40 (37 ± 2)	35-42 (37 ± 3)
Total	735-875 (794 ± 42)	795-900 (849 ± 45)	793-952 (854 ± 47)

Anterior spiracles (Fig. 8P) each 60-90 (76 ± 8) μm long, 50-68 (59 ± 5) μm wide across atrium, atrium wider than apodeme. *Posterior spiracles* similar to anterior ones, each 75-100 (88 ± 10) μm long, 70-75 (71 ± 2) wide across atrium. *Spiracular pore bands* each 1-2 pores wide in most of length, 3-5 pore wide near both ends, extending beyond apodemal base of spiracles. *Spiracular pores* (Fig. 8Q) usually quinquelocular, occasionally with 4 loculi, 5-6 μm in diameter, 51-60 in anterior spiracular pore band, 54-70 in posterior spiracular pore band. *Multilocular pores* (Fig. 8R) 5-9 μm in diameter, 5-8 (mostly 7) loculi, central loculus with a slit, around anal area, in transverse bands on abdomen, and in group beside each coxa. *Tubular ducts* of 2 types: first (Fig. 8S1) with slender, knobbed filament, numerous in submarginal and submedian areas, duct 8-11 μm long, 3-5 μm wide, inner filament 12-18 μm long; second (Fig. 8S2, S3, S4) with flowery tipped inner filament (Fig.), inner filaments slender (0.5-2 μm wide) (Fig. 8S2, S3) distributed in posterior part of abdomen or broad (3-4 μm wide) (Fig. 8S4) distributed in anterior part of abdomen and thorax and head, duct 10-18 μm long, 4-5 μm wide, inner

filament 8-20 μm long, flowery apex 4-7 μm wide. *Microducts* (Fig. 8T) scattered, 3 μm long, 2.5 μm wide.

Material examined

New South Wales: 2 ♀ on one slide, ex *Hydrangea* sp., Cremorne, 8.xi.1957, E.L. Jones (ANIC; WARI No. 167/57); 9 ♀ (3 ♀/slide except one slide with 2 ♀, another with 1 ♀), on stems and leaves of *Hydrangea* sp., Sydney, 6.xi.1959 (ANIC; WARI No. 18/60); 3 ♀ on one slide, on *Hydrangea* sp., Roseville, C.E. Chadwick (BCRI; WARI No. 18/60); 2 ♀, on *Hydrangea* sp., Roseville, 6.xii.1959, C.E. Chadwick (BCRI); 1 ♀, on *Hydrangea* sp., Lidcombe, 23.xi.1971 (BCRI); 2 ♀, on *Hydrangea* sp., Tumut, 30.xi.1979, R. Ahern (BCRI); 2 ♀, on flowering peach tree, Cheltenham, 9.xi.1982 (BCRI); 2 ♀, on stem of cherry tree, Beecroft, x.1984, K.O. Campbell (BCRI).

Distribution and host plants

In Australia, *P. hydrangeae* has been recorded only from south-east New South Wales where it has been collected on the exotic *Hydrangea* and *Prunus*. Overseas it is known from Europe, Japan and United States of America (Gill, 1988).

Apart from *Hydrangea* and *Prunus*, *P. hydrangeae* has been recorded from several other genera of host plants (see Williams & Kosztarab, 1972).

Discussion

The presence of the subdiscal seta in *P. hydrangeae* is unique amongst the Australian species. Moreover, *P. hydrangeae* differs from *P. decorata*, *P. floccifera* and *P. polygonata* and *P. psidii* in lacking submarginal tubercles. *Pulvinaria* sp. n. also lacks submarginal tubercles, but the ventral tubular ducts are not as numerous as in *P. hydrangeae* and more of the submarginal setae are bifid or fimbriate.

Pulvinaria maskelli Olliff

(Fig. 9)

Pulvinaria maskelli Olliff, 1891, pp. 667-669, pl. lxii; 1892, pp. 176-179, pl. xi;

Maskell, 1894, p. 76; Fernald, 1903, p. 135; Froggatt, 1910, p. 469; 1915, pp. 415-416, pl. ix; 1921, p. 10, fig. 5.

Signoretia atriplicis Maskell, 1892, p. 23, pl. iv fig. 8; 1894, p. 80 (synonymy).*Pulvinaria maskelli* var. *spinosior* Maskell, 1894, p. 78, pl. iv figs 6,7. New**Synonymy****Pulvinaria maskelli* var. *novemarticulata* Green, 1915, p. 48. New Synonymy*Pulvinaria nuytsiae* Maskell, 1897, pp. 313-314; Froggatt, 1915, pp. 416-417; 1921, p. 10. New Synonymy*Ctenochiton* (?) *nuytsiae*: Fuller, 1897, p. 1345 (male); 1899, p. 458 (synonymy with *p. nuytsiae* by indication).*Pulvinaria maskelli* var. *nuytsiae* Maskell, Fuller, 1899, p. 458 (by indication); Fernald, 1903, p. 136.*Pulvinaria newmani* Froggatt, 1915, p. 417, pl. x, fig. i; 1921, p. 12, fig. 6. New**Synonymy**

*This synonym is suggested based on examination of the original description.

Suggested common name: Saltbush cottony soft scale

Types

Lectotype of *Pulvinaria maskelli* (present designation): ♀, New South Wales, labelled: "*Pulvinaria, maskelli* Olliff, 2nd stage female [actually it is an adult female], 1892 W.M.M." (ANIC from NZAC; Maskell's original slide). **Paralectotypes** (present designation): 1 ♀, 1 anterior part of ♀, same data as lectotype (NZAC; Maskell's original slides).

Olliff's type material of *Pulvinaria maskelli* cannot be found in BCRI, where Olliff used to work, nor in any other collections and museums in Australia, although it seems that the author collected a lot of specimens and reared all the stages (Olliff, 1891,

1892). However, it is obvious that some of Olliff's material is in NZAC because Maskell (1894, p. 77), in synonymising *Signoretia atriplicis* with *P. maskelli*, mentioned that he had received specimens of *P. maskelli* from Olliff and had made a comparison from "prepared specimens [slide-mounts] of both". This means that Maskell's slides include not only his original specimens of *S. atriplicis*, but also Olliff's specimens of *P. maskelli*. In the NZAC, Maskell's slides of *P. maskelli* are labelled in two ways: three are labelled: "*Signoretia, atriplicis*, (Australia), 1891 W.M.M." with the name "*Signoretia, atriplicis*" crossed out and changed to "*Pulvinaria, maskelli*" (these must be his original slides of *S. atriplicis*); another three are labelled: "*Pulvinaria, maskelli* Olliff, 1892 W.M.M."; the latter are almost certainly the specimens which Maskell received from Olliff and are accepted here as part of type series of *P. maskelli*, the remainder of Olliff's collection being lost. Therefore the lectotype and paralectotypes were designated from this material (see above).

For the type locality and host plant, Olliff (1892, p. 178) stated that the species is from "Wentworth and Balranald, New South Wales; N.W. Victoria; on various species of saltbushes, especially those known as *Rhagodia hastata*, *Atriplex vesicaria* and *A. nummularia*". The host plant and locality of the material that Olliff sent to Maskell is unknown as it is not specified on any of labels.

Lectotype of *Signoretia atriplicis* Maskell (present designation): ♀, New South Wales, labelled "*Pulvinaria, maskelli* [with "*Signoretia, atriplicis*" crossed out], adult female, (Australia), 1891 W.M.M." (ANIC from NZAC; Maskell's original slide).

Paralectotypes (present designation): 2 immature ♀ on one slide, same data as lectotype (NZAC); 6 first instar nymphs, labelled "*Pulvinaria, maskelli* Olliff, 1891 W.M.M." (NZAC); 2 ♀, ex dry material in cylindrical box, label on lid: "*Pulvinaria, maskelli*, Olliff, =*Signoretia atriplicis* Maskell, Australia" (NZAC); Additional dry material in cylindrical box, same data as above (NZAC).

Maskell (1892) described *Signoretia atriplicis* and later (1894) synonymised it with *P. maskelli* because he noticed that his paper containing *S. atriplicis* was delayed in

printing until May 1892, although it was read in October, 1891, one month before the appearance of Olliff's description of *P. maskelli*.

The host plant of the type of *S. atriplicis* is *Atriplex* sp. (*A. halimus* ?) (Maskell, 1891, p. 24) and the locality is Wentworth, New South Wales (Maskell, 1894, p. 77).

The types of *Pulvinaria maskelli* var. *spinosior* Maskell is not available for examination at present because it is on loan to Dr Williams, BMNH, from Dr C.F. Morales, NZAC. However, it is probably a synonym of *P. maskelli* based on examination of the original descriptions.

In his original description of *P. maskelli* var. *spinosior*, Maskell stated that it was on *Frenela* (*Callitris*) *robusta*, "Murray Pine"; its collection locality was not known, but the tree is a native of South Australia.

Lectotype of *Pulvinaria maskelli* var. *novemarticulata* (present designation): ♀ (encircled in black on slide), Victoria, 2 labels: "*Pulvinaria, maskelli nov[em]articulata*, Green, (Type) on *Hymenanthera*, Mallee, Victoria, Australia, coll. C. French, 161", "TYPE" [printed in red and surrounded by red circle] (BMNH). **Paralectotypes** (present designation), 5 ♀, on same slide as lectotype (BMNH).

Lectotype of *Pulvinaria nuytsiae* (present designation): ♀ (encircled in black on slide), Western Australia, labelled "*Pulvinaria nuytsiae*, 2 adult females, 1896, W.M.M." (ANIC from NZAC; Maskell's original slide). **Paralectotypes** (present designation): 1 ♀, on same slide as lectotype (NZAC); 1 anterior part of female, 1 first instar nymph, same data as lectotype (NZAC; Maskell's original slides); 1 ♀, ex dry material in cylindrical box, label on lid: "*Pulvinaria, nuytsiae*, Maskell., 1896, W. Australia" (NZAC); Additional dry material in cylindrical box, same data as above (NZAC).

The host plant of the types of *P. nuytsiae* is *Nuytsia floribunda* and the specimens were collected at Walkaway in Western Australia (Maskell, 1897, p. 314).

Lectotype of *Pulvinaria newmani* (present designation): ♀, western Australia, ex dry stem; 5 labels: "535, WA", "Harvey Dale W.A., Newman, (5) 1911", "Type W.W.F., Cat II 12, 1921", "*Pulvinaria newmani*, W. Australia" and "*P. newmani* **Paralectotypes** Froggatt, Type, W. Aust." (BCRI). **Paralectotypes** (present designation): 1 ♀ same data

as lectotype (BCRI). 1 ♀, remounted from Froggatt's original slide labelled: "*Pulvinaria, newmani*, n.sp., *Jacksonia*. W.A., Newman, Type" [Froggatt's handwriting] (BCRI).

There were three manuscript names, *Pulvinaria quandong* Froggatt in BCRI and *P. hilli* Froggatt and *P. eucalypti* in MVM. All specimens of these three manuscript species are identical with *P. maskelli*.

Diagnosis

Appearance: Adult female transversely shrivelled, brown or dark-brown, 4.0-7.0 mm long, 4.0-5.0 mm wide. Ovisac white, 4.0-12.0 mm long, 4.0-4.6 mm wide, fairly convex, with a longitudinal ridge in middle and numerous transversely shallow lines, .

Slide-mounted adult female: Marginal setae truncate, strong and stout, some with large base; anal plates reticulated dorsally, with 2 inner margin setae; ventral thickenings triangular; dorsal microducts on dorsum with expanded inner filament like a fan plus long slender tail; anal ring with 6 setae.

Description of adult female (30 slide-mounted specimens measured, Fig. 9)

Body (Fig. 9A) elongate oval to broadly oval, size various, 2.5-9.5 (5.7 ± 2.9) mm long, 1.2-5.5 (3.3 ± 1.6) mm wide, length 1.4-2.3 times width. *Anal cleft* 290-1,500 (834 ± 467) μm long, 0.11-0.18 body length.

Margin: Marginal setae (Fig. 9B1) 25-50 μm long, stout, straight, apex truncate, a few very strong (Fig. 9B2) and with larger based than others (almost always with 1 or 2 near opening of anal cleft); distributed as follows (large based setae in square bracket): 60-158 [0-7] between anterior spiracular furrows, 14-40 [0] between anterior and posterior spiracular furrows on each side, 39-118 [0-6] between each posterior spiracular furrow and anal cleft; density of marginal setae variable. *Spiracular setae* (Fig. 9C1, C2) 3 in each spiracular furrow; median seta 83-98 μm long, 1.1-2.0 times as long as lateral setae, slightly expanded near apex, bluntly pointed, mostly slightly curved; lateral setae 42-78 μm long, straight or slightly curved, bluntly pointed. *Spiracular sclerotisation* absent.

Dorsum: *Dorsal setae* (Fig. 9E) 12-18 μm long, spine-like, scattered.

Submarginal tubercles absent. *Disc pores* (Fig. 9G1) 3-5 μm in diameter, sparsely scattered. *Discoidal pores* (Fig. 9G2) 4-7 in diameter, in group of 36-85 anterior to anal plates. *Tubular ducts* not detectable. *Microducts* (Fig. 9I) scattered, 3 μm long, 2 μm wide, inner filament expanded as fan (6-10 μm long, 4-8 μm wide) with a long slender tail (8-14 μm long). *Anal plates* (Fig. 9J1) triangular, 155-230 (198 ± 26) μm long, 80-120 (94 ± 15) μm wide, dorsal surface reticular on anterior two-thirds; anterolateral margin straight or slightly convex, 95-140 (114 ± 17) μm long, posterolateral margin usually convex, 110-165 (132 ± 18) μm long. Each plate with all setae stout, truncate (Fig. 9J1) except fringe and subapical setae (Fig. 9J2) slender and pointed, 2 apical setae 25-62 μm long, 2 subapical setae 25-62 μm long, and 2 inner margin setae 20-45 μm long, position of inner margin setae variable, measuring from anterior apex of inner margin, anterior one at 1/2 (Fig. 9J1(1)) to 2/3 (Fig. 9J1(2)) distance along inner margin, posterior one at 2/3 to 4/5 distance along inner margin. *Ventral thickenings* (Fig. 9J2) triangular. *Fringe setae* 2 pairs, 18-60 μm long. *Anal ring* (Fig. 9K) subcircular, 70-120 (88 ± 18) μm long, 75-100 (88 ± 12) μm wide, with 6 setae 130-325 μm long; translucent pores in 1-3 rows, each pore 3-5 μm in maximum dimension.

Venter: *Submarginal setae* (Fig. 9L) 15-30 μm long, slender, straight, acute; distributed as follows: 15-30 between anterior spiracular furrow, 5-9 between anterior and posterior spiracular furrows on each side, 14-25 between each posterior spiracular furrow and anal cleft. *Ventral setae* (Fig. 9M) 10-28 μm long except a pair near labium up to 70 μm long, similar to submarginal setae. *Interantennal setae* 3-5 pairs, 13-83 μm long. *Prevulvar setae* 2 pairs, 70-150 μm long. *Eyes* detected on some specimens, oval, 12-15 μm in maximum dimension. *Antennae* (Fig. 9N) well developed, 7-9 (mostly 9) segmented, 375-675 (510 ± 112) μm long, third segment longest; segment I 70-110 (94 ± 16) μm wide, 45-100 (72 ± 16) μm long. Length of segments II to IX: 45-90 (66 ± 18) μm , 75-165 (117 ± 27) μm , 50-100 (82 ± 19) μm , 38-80 (64 ± 18) μm , 25-45 (32 ± 8) μm , 25-35 (31 ± 5) μm , 25-40 (29 ± 8) μm and 30-50 (39 ± 7) μm , respectively; number of hair-like setae: I, 2-3; II, 2-3; III, 1-3; IV, 1-2; V, 0-3; VI, 2-3; VII, 0;

VIII, 0-1; IX, 1-2; number of fleshy setae: VII, 1; VIII, 1; IX, 5-7. *Clypeolabral shield* 170-240 (206 ± 21) μm long, 170-230 (205 ± 22) μm wide. *Labium* 65-100 (87 ± 15) μm long, 120-150 (136 ± 10) μm wide, with 4 setae 25-38 μm long on each side. *Legs* (Fig. 9O) well developed, with tibiotarsal sclerotisation and free articulation; claws without denticle; tarsal digitules slender, knobbed, 65-105 μm long; claw digitules broad, expanded at apex, 40-65 μm long. Leg lengths as follows:

Segments	First leg (μm)	Second leg (μm)	Third leg (μm)
Coxa	90-170 (124 ± 25)	100-180 (132 ± 26)	110-190 (139 ± 31)
Tro.+Fem.	240-455 (331 ± 76)	300-470 (357 ± 75)	300-480 (360 ± 80)
Tibia	175-370 (271 ± 65)	195-370 (280 ± 64)	195-370 (281 ± 64)
Tarsus	100-150 (123 ± 19)	105-165 (137 ± 26)	105-180 (135 ± 27)
Claw	38-45 (39 ± 5)	38-45 (41 ± 2)	38-45 (41 ± 3)
Total	653-1,188 (907 ± 202)	708-1,230 (992 ± 201)	708-1,263 (979 ± 208)

Anterior spiracles (Fig. 9P) each 80-160 (106 ± 52) μm long, 52-115 (80 ± 24) μm wide across atrium, atrium more narrow than apodeme. *Posterior spiracles* similar to anterior ones, each 80-180 (117 ± 60) μm long, 70-140 (98 ± 30) μm wide across atrium.

Spiracular pore bands each 2-3 pores wide, extending beyond spiracular apodemal base.

Spiracular pores (Fig. 9Q) quinquelocular, 5-6 μm in diameter, 34-89 in anterior spiracular pore band, 46-87 in posterior spiracular pore band. *Multilocular pores* (Fig.

9R) 6-8 μm in diameter, 6-13 loculi, around anal area, and in transverse bands on abdomen. *Tubular ducts* (Fig. 9S1, S2) with flowery tipped inner filament, numerous in submarginal area, scattered in median area, absent in area anterior and posterior to base of antennae; duct 10-30 μm long, 4-6 μm wide, inner filament 15-20 μm long, 2-3 μm wide for filament, 4-7 μm wide for flowery apex. *Microducts* (Fig. 9T) scattered, 4-6 μm long, 2 μm wide; in some specimens microducts 9-10 μm long and inner filament with 3 finger-like projections.

Other material examined

New South Wales: 2 ♀, ex roots of saltbush, nr. Deniliquin, 1.xi.1979, W.A. Low (ANIC); 3 ♀, on saltbush, Coolabah, 13.x.1904, R.W. Peacock (BCRI); 2 ♀, Brewarrina, 28.viii, 1913 (BCRI); 2 ♀ and 1 immature ♀ on one slide, on saltbush, Coonamble, 19.viii.1937 (BCRI); 6 ♀ (2 ♀/slide), on oldman saltbush, *Atriplex* sp., Balranald, 31.vii.1953, C.J. Hood (BCRI); 6 ♀, on roots and lower stems of *Atriplex vesicaria*, N.W. of Deniliquin, 10.ix.1979, W. Mulham (BCRI); 2 ♀, 3 immatures (1+2/slide), on *Atriplex nummularia*, Western Boundary of "The Ringe", 15 ml. N. of Hatfield, 6.xi. 1980, B. Semple (BCRI); 2 ♀, 1 immature, on bushes, Oxley Stn., N.W. of Hay, 16.vii.1981, G.J. Goodyer (BCRI); 3 ♀, on saltbush, Brewarrina, 20.ix.1981, M. Overton (BCRI); 2 ♀, on *Atriplex nummularia*, 'Tylden', c. 28 miles N. of Balranald, 10.x.1985, D. Cliff (BCRI); 1 ♀, from bladder saltbush, *Atriplex vesicaria*, Freshwater Station, c. 8 miles NW of Shearing Shed adjacent to Mossgiel, Oxley Road, Riverine Plain, x.1985, D. Cliff (BCRI). **South Australia:** 4 ♀ on one slide, on *Rhagodia spinesens*, Musgrave R., Sir John Cleland (ANIC; WARI No. 185/54); 6 ♀ (3 ♀/slide), on *Rhagodia spinescens*, Waikerie, 31.viii.1955, T.O.B. (ANIC; WARI No. 127/55); 3 ♀ (2 + 1 ♀/slide), on *Atriplex vesicaria*, Koonamore, viii. 1956, C.M. Eardley (ANIC; WARI No. 159/56); 15 ♀ (2 ♀/slide except one slide with 3 ♀), on *Atriplex vesicaria* & *A. stipitata*, viii, 1956, C.M. Eardley (ANIC; WARI No. 159/56); 8 ♀ (3 ♀/slide except one slide with 2 ♀), on ? *Bassia*, Flinders Range, ix.1958 (ANIC; WARI No. 188/58); 9 ♀ (2 ♀/slide except three slides each with 1 ♀), on *Atriplex vesicaria*, Koonamore, viii.1959, C.M. Eardley (ANIC; WARI No. 212/59); 6 ♀ (2 ♀/slide), on stems of *Eucarya* (now *Santalum*), Kimba, x.1959, D.E. Symon (ANIC; WARI No. 239/59); 5 ♀ (2+3 ♀/slide), on *Atriplex* sp., Berri, 1.x.1963, M. Kuchel (ANIC); 11 ♀ (3 ♀/slide except one slide with 2 ♀), on *Lycium australe*, Chowilla Station, 13.vii.1966, R.H. Kuchel (ANIC; WARI No. 32/66); 9 immatures (2/slide except one slide with 3), on *Santalum spicatum*, nr Koonalda, H. s. far W. of S. Aust., ii.1967, D.E. Symon (ANIC); 7 ♀ (2 ♀/slide except one with 3 ♀), on stems of *Rhagodia*, Paralana Springs, 24.viii.1968, F.D. Morgan (ANIC; WARI No. 28/68); 6 ♀ (3 ♀/slide); 5 ♀ (2 ♀/slide except one with 1 ♀), on

? *Leichhardtia*, Hinks National Park, Eyre Pen., 9.x.1968, D.E. Symon (ANIC; WARI No. 46/68); 3 ♀, on *Atriplex vesicaria*, Spring Dam, via Yunta, 3.ix.1974, A. Tiver (ANIC); 4 ♀, on *Atriplex vesicaria*, Koonamore Stn., vi.1976, D. Coleman (ANIC; WARI No. 11/76); 3 ♀, 25 first instar nymphs (10+8+7/slide), on *Callitris canescens*, nr. Murray Bridge, 10.ix.1978, D.A. Maelzer (ANIC; WARI No. 17/78); 2 ♀, on *Callitris canescens*, Murray Bridge, 16.vii.1979, D.A. Maelzer (ANIC); 4 ♀, on *Rhagodia obovata* Coast Cliffs, x. 1885, T.S. Lea (BMNH); 5 ♀, on quandong, Eyre Pen., 4 km E. of Coomaba (S. of Toolagie), 6.x.1979, G.F. Gross (SAM). **Victoria:** 3 ♀, Mallee, 15.ii.1915, C. French 588 (BCRI); 3 ♀, Mallee, 1915, J.E. Dixon (BCRI); 2 ♀, on quandong, Stawell, 1919, French (BCRI); 4 ♀, Mallee, C. French (BMNH; Reg No. 1916. 88); 4 ♀ on one slide, Mallee (BMNH; Reg.No.1916. 100; JBE 107); 2 ♀ on one slide, on *Beyeria viscosa*, Mallee, 1925, J.E. Dixon No-41 (BMNH; IBE 1414); 3 ♀, on *Santalum*, 1925, J.A. Hill No-42 (BMNH; IBE 1415); 4 ♀ on one slide, on *Callitris*, C. French 156-a (BMNH; 1940, 180); 4 ♀, on one slide, on *Eucalyptus* sp., Mallee, C. French 150 (BMNH, 1940, 180); 1 ♀, on *Beyeria*, Mallee (BMNH); 3 ♀, Mallee, presented by C. French, 8.xi.1915 (MVM); 2 ♀, on *Beyeria viscosa*, Lake Hattah, 5.v.1919, J.E.D. (MVM); 1 ♀, on *Santalum*, 12.iv.1919 (MVM); 2 ♀, on *Myoporum*, Lake Hattah, 1919, J.E.D. No. 4 (MVM); 2 ♀, on *Santalum*, Lake Hattah, x.1919, J.E. Dixon (MVM); 2 ♀ (SAM); 1 ♀, on *exocarpi*[sic], 2.ii.1920, J.E.D. (MVM); 2 ♀, on *Salicornia* sp., Phillip Isl., 19.xii.1921. C. French (MVM); 2 ♀, Red Cliffs, 25.x.1960, J. Nelson (MVM); 2 ♀, 0-6 km N. NE of Chinaman Well, Big Desert, 11.x.1982, A. Yen (MVM); 1 ♀, on *Dodonaea*, Mildura, Burrough (MVM); 2 ♀, on *Eucalyptus*, Lake Hattah, Dixon (MVM); 3 ♀, Mallee, 1915, J.E. Dixon (SAM). **Western Australia:** 1 ♀, ex *Atriplex rhagodioides*, Pingrup, 23.vi.1982, B. Clark (ANIC); 1 ♀, ex *Atriplex* sp., Pingrup, 24.vi.1982, B. Alfham (ANIC); 1 ♀, ex dry material in rectangular box, label on the back: "*Pulvinaria nuytsiae* Mask. Australia #488" (NZAC). **Localities unknown:** 7 ♀ on one slide, on *Atriplex* sp., W.W. Froggatt (BMNH, 1940, 180); 3 ♀, ex dry material in rectangular box #222 (NZAC).

Distribution and biology

This endemic Australian species has been recorded from south-west Western Australia, south-east South Australia, Victoria and northern and south-west New South Wales.

Host plants are varied including saltbushes and various trees and shrubs. Known host-plant genera are *Atriplex*, *Beyeria*, *Callitris*, *Dodonaea*, *Eucalyptus*, *Hymenanthera*, *Jacksoni*, *Lycium*, *Myoporum*, *Nuytsia*, *Rhagodia*, *Salicornia*, *Santalum*, and possibly *Bassia* and *Leichhardtia*.

Olliff (1892) observed the biology of *P. maskelli* and stated that the male requires about sixty-three days from the time of hatching to maturity, and the female needs an additional fifteen days before producing its ovisac.

Discussion

Pulvinaria maskelli is very easily separated from any other pulvinariine species in Australia because it has some unique autapomorphies. The marginal setae are strong and truncate, and there are always some marginal setae larger and with a bigger base than the rest. The anal plates are reticulate on the dorsum and have truncate apical and inner margin setae. The dorsal microducts have an expanded inner filament plus a long tail and the anal ring has 6 setae.

However, the marginal setae of *P. maskelli* are similar to those of the monotypic genus *Megapulvinaria* Young (1982), but *Megapulvinaria* has always more than three spiracular setae.

Intraspecific variation: *Pulvinaria maskelli* is a very common species on saltbush and also other host plants, and is distributed from the south-west to south-east Australia. There are several variable characters, including the size and shape of the ovisac and insects, the density of marginal setae, the number of large-based marginal setae, the position of the two inner margin setae on the anal plates, the number of antennal segments and other characters. However, careful examination of the type specimens of its synonyms, *P. newmani* and *P. nuytsiae* and *P. maskelli novemarticulata*, and all other

specimens available from different localities leads to the conclusion that there is no obvious trend in the variation. All attempts to group specimens geographically failed and variation due to host-plant association is unclear, although specimens collected from the saltbush genus *Atriplex* seem to have a shorter ovisac and less crowded marginal setae. The latter difference may be due to the sites where insects feed, because some specimens from roots or the lower part of plants have slightly shorter marginal setae. The populations of *P. maskelli* cannot be divided into forms because the characters do not covary, e.g., there is no correlation between density of marginal setae and position of inner margin setae on the anal plates.

***Pulvinaria mesembryanthemi* (Vallot)**

(Fig. 10)

Coccus mesembryanthemi Vallot, 1829, p. 468.

Pulvinaria mesembryanthemi (Vallot), Signoret, 1873, p. 39; Fernald, 1903b, p. 136;

De Lotto, 1967, p. 793, fig. 13; Hodgson, 1967, p. 203, fig. 2; 1968, p. 164;

Gill, 1979, pp. 241, 247, 249, fig. 5; 1988, p. 89, fig. 39.

Pulvinariella mesembryanthemi (Vallot), Borchsenius, 1953, p. 387; 1957, pp. 253-256, fig. 225; De Lotto, 1979, p. 254.

Suggested common name: Pigface cottony soft scale (in USA it is called 'Iceplant scale' (Gill, 1988))

Types

Not examined

Diagnosis

Appearance: Adult female yellow-green with some black dots in median area, shrivelled transversely, 2.5-3.5 mm long, 2.0-3.4 mm wide. Ovisac white, 1.5-4.2 mm

long, 1.9-2.9 mm wide, convex, usually with a distinctive longitudinal furrow in middle and numerous shallow longitudinal grooved lines at both sides.

Slide-mounted adult female: Marginal setae stout, slightly curved or straight, bluntly tipped, two sizes in irregular two rows, inside row short and small and outside row long and large; middle spiracular setae much longer than lateral ones (2.7-4.8 times); numerous microducts in group around labium.

Description of adult female (14 slide-mounted specimens measured, Fig. 10)

Body (Fig. 10A) oval to broadly oval, 2.1-4.7 (3.1 ± 0.8) mm long, 1.8-3.0 (2.3 ± 0.4) mm wide, times length 1.1-1.6 times width. *Anal clefts* 250-500 (338 ± 57) μm long, 0.10-0.13 body length.

Margin: Marginal setae (Fig. 10B) stout, bluntly tipped; of 2 sizes: small ones 12-20 μm long, usually straight, distributed in inside row, large ones 30-45 μm long, mostly curved, in outside row; distributed as follows (including both small and large ones): 28-41 between anterior spiracular furrows, 10-14 between anterior and posterior spiracular furrows on each side, 19-31 between each posterior spiracular furrow and anal cleft. *Spiracular setae* (Fig. 10C) 3 in each spiracular furrow; median seta 35-48 μm long, 2.7-4.8 times as long as lateral setae, often widest near apex; lateral setae 8-15 μm long, pointed. *Spiracular sclerotisation* absent.

Dorsum: Dorsal setae (Fig. 10E) 7-8 μm long, spine-like, scattered.

Submarginal tubercles absent. *Disc pores* not detectable. *Discoideal pores* (Fig. 10G) 4-6 in diameter, in group of 18-52 anterior to anal plates, often associated with several dorsal setae. *Tubular ducts* (Fig. 10H) sparsely scattered, duct 5-6 μm long, 3 μm wide, inner filament 3 μm long. *Microducts* (Fig. 10I) scattered, 3 μm long, 1.5 μm wide, inner filament about 5 μm long. *Anal plates* (Fig. 10J1) triangular, 118-180 (165 ± 19) μm long, 75-90 (81 ± 6) μm wide; anterolateral margin straight or slightly convex, 85-120 (100 ± 9) μm long, posterior margin slightly convex, 108-140 (126 ± 9) μm long. Each plate with 4 apical setae 20-30 μm long, 3 subapical setae 42-80 μm long, and no inner margin setae. *Ventral thickenings* (Fig. 10J2) elongate triangular. *Fringe setae* 2 pairs,

20-70 μm long. *Anal ring* 60-80 (69 ± 7) μm wide (length not measured due to orientation), with 8 setae 160-260 μm long, translucent pores in 1-3 rows, each pore 3-5 μm in maximum dimension.

Venter: Submarginal setae (Fig. 10L) 12-18 μm long, slender; distributed as follows: 17-24 between anterior spiracular furrows, 8-9 between anterior and posterior spiracular furrows on each side, 17-27 between each posterior spiracular furrow and anal cleft. *Ventral setae* (Fig. 10M) 7-35 μm long, similar to submarginal setae.

Interantennal setae 3-4 pairs, 12-75 μm long. *Prevulvar setae* 3 pairs, 60-80 μm long. *Eyes* oval, 12-35 μm in maximum dimension. *Antennae* (Fig. 10N) well developed, 7-8 (usually 8) segmented, 277-430 (365 ± 44) μm long, third segment longest; segment I 60-80 (71 ± 7) μm wide, 40-60 (51 ± 9) μm long; length of segments II to VIII: 50-75 (60 ± 9) μm , 55-80 (69 ± 8) μm , 32-70 (77 ± 13) μm , 25-40 (25 ± 6) μm , 25-35 (31 ± 3) μm , 20-35 (29 ± 4) μm and 30-50 (42 ± 7) μm , respectively; number of hair-like setae: I, 2-3; II, 1-3; III, 0-1; IV, 0-1; V, 1-3, VI, 0; VII, 1-2; VIII, 1-3; number of fleshy setae: VI, 1; VII, 1; VIII, 3-7. *Clypeolabral shield* 150-180 (169 ± 100) μm long, 160-180 (167 ± 7) μm wide. *Labium* 60 μm long, 80-110 (100 ± 10) μm wide, with 4 setae 20-30 μm long on each side. *Legs* (Fig. 10O) well developed, with tibiotarsal sclerotisation and free articulation; claws without denticle; tarsal digitules slender, knobbed, 52-75 μm long; claw digitules broad, expanded at apex, 30-50 μm long. Leg lengths as follows:

Segments	First leg (μm)	Second leg (μm)	Third leg (μm)
Coxa	90-110 (98 ± 7)	100-120 (104 ± 7)	100-120 (109 ± 7)
Tro.+Fem.	220-310 (268 ± 31)	255-330 (284 ± 25)	260-320 (283 ± 24)
Tibia	150-200 (184 ± 23)	180-240 (205 ± 22)	170-230 (204 ± 21)
Tarsus	90-120 (105 ± 9)	100-120 (111 ± 9)	100-130 (115 ± 10)
Claw	25-32 (28 ± 3)	30-35 (33 ± 2)	30-35 (32 ± 2)
Total	588-772 (682 ± 67)	670-845 (738 ± 63)	640-820 (743 ± 62)

Anterior spiracles (Fig. 10P) each 60-85 (74 ± 8) μm long, 55-70 (59 ± 7) μm wide across atrium, atrium wider than apodeme. *Posterior spiracles* similar to anterior ones, each 70-

100 (82 ± 9) μm long, 55-80 (68 ± 7) μm wide across atrium. *Spiracular pore bands* each 2-4 pores wide, extending beyond spiracular apodemal base. *Spiracular pores* (Fig. 10Q) quinquelocular, 4-5 μm in diameter, 30-57 in anterior spiracular pore band, 37-66 in posterior spiracular pore band. *Multilocular pores* (Fig. 10R) 7-8 μm in diameter, 9-12 loculi, distributed around anal area and in transverse rows on abdominal segments, and in group beside hind coxa. *Tubular ducts* of 2 types: first (Fig. 10S1) with slender inner filament, confined to outer part of submarginal area, duct 4-12 μm long, 3-4 μm wide, inner filament slender, 3-5 μm long, 1-1.5 μm wide; second (Fig. 10S2, S3) with flowery tipped inner filament, distributed over venter, numerous in submarginal area, duct 8-12 μm long, 3-4 μm wide, inner filament 20-30 μm long, 1-3 μm wide, flowery apex 5-6 μm wide. *Microducts* (Fig. 10T) in group around labium and scattered over venter, 4-5 μm long, 2 μm wide.

Material examined

Australian Capital Territory: 1 immature ♀, ex *Carpobrotus* sp., 10 AH Cres., Ainslie, 1.xi.1983, P.J. Gullan (ANIC); 3 ♀, ex *Carpobrotus* sp., O'Connor, 26.v.1988, T. Watson (ANIC). **New South Wales:** 1 ♀, ex *Carpobrotus* sp., Congo, 13.ii.1983, M.S. Upton (ANIC); 2 ♀, on succulent, Halliday's Point, 24.ix.1984, D. Evans (BCRI). **Queensland:** 2 ♀, ex *Carpobrotus* sp., Kingaroy, 19.xi.1982, D.J. Rogers JFD 617 (DPI); 3 ♀, on ?*Sesuvium portulacastrum*, Kingaroy, 22.xi.1982, J. Baker JFD 613 (DPI); 3 ♀, ex ?*Carpobrotus glaucescens*, Brisbane, 8. ix.1986, G. Daniels JFD 2825 (DPI); 3 ♀, on *Mesembryanthemum* sp., Goodna, 29.ix.1986, W. Farler (DPI; JFD 2831). **South Australia:** 6 ♀, on *Mesembryanthemum crystallinum*, WARI, vi.1972, K.M. Doull (ANIC; WARI No. 10/72); 8 ♀ (4 ♀/slide), on *Mesembry^{an}themum* sp., nr. Centr. Animal House, WARI, 20.xi.1973, D. Britza (ANIC); 4 ♀ (1 ♀/slide except one slide with 2 ♀), on *Atriplex vesicaria*, Spring Dam, via Yunta, 3.ix.1974, A. Tiver (ANIC); 6 ♀ (2 ♀/slide), on *Mesembryanthemum* sp., in a home garden, Adelaide, 2.iii.1976, J. Scarvalis (ANIC); 2 ♀, Middleton, 25.xii.1976, R.E. Hill (SAM); 3 ♀, Mitcham, 2.xi.1977, R.V. Southcott

(SAM); 3 ♀ on two slides, ex *Delosperma lehmannii* and *Lampranthus glaucus*, Botanic Garden, Adelaide, 21.v.1980, K.S. Hagen (ANIC; WARI No. 31/80). **Tasmania:** 8 ♀, on pigface, Riverside, 1.ix.1977 M255-M262 (TDA). **Victoria:** 2 ♀, on pigface, Melbourne, 8.iv.1969, L.D. Crawford (MVM); 2 ♀, on *Mesembryanthemum* sp., Box Hill North, 9.iv.1969. L.D. Crawford (ANIC; WARI No. 20/69); 1 ♀, on *Mesembryanthemum*, Box Hill Nth, vii. 1969, (ANIC; WARI No. 20/69); 3 ♀, on *Mesembryanthemum* ? *crystallinum*, Eltham, i. 1972, N.C. Stewart (ANIC). **Western Australia:** 4 ♀, ex *Carpobrotus edulis*, Mosman Park, 19.i.1977, K.T. Richards (ANIC); 2 ♀ and 1 immature ♀, ex *Carpobrotus edulis*, Jundacot Marsupial Res. 19.iv.1979, L. Collins (ANIC); 2 ♀, W. Pickering, 28.ix.1976, (WADA); 2 ♀, on *Gastrolobium oiloburn* (WADA).

Distribution and host plants

In Australia, *P. mesembryanthemi* has been recorded, mostly along the coastline, from all states and territories except the Northern Territory. It occurs also in Southern Africa, the Mediterranean region, Argentina and United States of America (Gill, 1988).

The main host plants are *Carpobrotus* and *Mesembryanthemum*, but it also occurs on *Atriplex*, *Delosperma*, *Lampranthus*, *Gastrolobium* and possibly *Sesuvium*.

Discussion

The marginal setae of *P. mesembryanthemi* are similar to those of *P. salicorniae* and *P. thompsoni* in Australia, but *P. mesembryanthemi* is easily distinguished from later two species because the body of *P. salicorniae* is usually wider than long, and *P. thompsoni* has spiracular sclerotisation and too great in number of marginal setae.

De Lotto (1979) established the genus *Mesembryna* in which the marginal setae are similar to those of *P. mesembryanthemi*, but *Mesembryna* has no spiracular setae and lacks tibiotarsal sclerotisation. De Lotto (1979) also stated that *P. mesembryanthemi* originated somewhere in the southern tip of the African continent and is an immigrant in

Russia, other countries of Europe and California. He did not mention the species in Australia.

Pulvinaria polygonata (Cockerell)

(Figs 2E & F, 11)

Pulvinaria polygonata Cockerell, 1905, p. 131; Robinson, 1917, p. 10; Morrison, 1920, p. 184, fig. 23; Williams, 1985a, p. 228.

Pulvinaria cellulosa Green, 1909, p. 262, pl. xcix, figs. 1-10; Summerville, 1934, pp. 483-486, pl. 127 figs. 1-4; Borchsenius, 1957, p. 219 (synonymy).

Chloropulvinaria polygonata (Cockerell), Borchsenius, 1957, p. 219-220; Wang, 1982, p. 34; Young, 1982, p. 158; Williams, 1985a, p. 228.

Macropulvinaria polygonata (Cockerell), Tao, Wong & Chang, 1983, p. 87, 89, fig. 25.

Suggested common name: Citrus cottony soft scale

Types

Not examined

Diagnosis

Appearance: Adult female transversely shrivelled, brown, 2.0-2.5 mm long, 2.0-3.0 mm wide. Ovisac white, 3.0-4.0 mm long, 2.0-3.0 mm wide.

Slide-mounted adult female: Usually with more than 3 spiracular setae; some marginal setae deeply branched; dorsum with cell-like clear areas; submarginal tubercles present; spiracle often surrounded by sclerotic plate.

Description of adult female (17 slide-mounted specimens measured, Fig. 11)

Body (Fig. 11A) oval to broadly oval, 2.0-4.8 (3.7 ± 0.7) mm long, 1.2-3.3 (2.5 ± 0.5) mm wide, length 1.1-2.1 times width. *Anal cleft* 300-620 (471 ± 87) μ m long, 0.10-0.16 body length.

Margin: *Marginal setae* (Fig. 11B) 30-100 μm long, slender, straight or curved, mostly acute, some or half setae bifid or branched; distributed as follows: 64-91 between anterior spiracular furrows, 19-34 between anterior and posterior spiracular furrows on each side, 49-80 between each posterior spiracular furrow and anal cleft. *Spiracular setae* (Fig. 11C) 3-6 (usually 4-5) in each spiracular furrow, one longer than others, usually in middle, 1.3-3.3 (except one 5.5) times as long as other setae; longest seta 50-75 μm long, slightly curved, bluntly pointed; other setae 20-50 (except one 10) μm long, only slightly curved, bluntly pointed. *Spiracular sclerotisation* absent.

Dorsum: *Derm* with cell-like clear areas (Fig. 11D). *Dorsal setae* (Fig. 11E) 7-10 μm long, spine-like, scattered. *Submarginal tubercles* (Fig. 11F) 7-14 around body, 9-10 μm in diameter. *Disc pores* not detectable. *Discoidal pores* (Fig. 11G) 3-5 μm in diameter, in group of 34-56 in median area anterior to anal plates, occasionally 2 of these pores touching, forming a 8-shaped pore. *Tubular ducts* (Fig. 11H) scattered, duct 6-12 μm long, 3 μm wide, inner filament 8-10 μm long. *Microducts* (Fig. 11I) in cell-like clear areas, each 2 μm long, 2 μm wide, inner filament 4 μm long. *Anal plates* (Fig. 11J1) triangular, 135-165 (151 ± 10) μm long, 70-95 (86 ± 8) μm wide; anterolateral margin concave, 70-115 (98 ± 12) μm long, posterolateral margin convex, 115-135 (125 ± 7) μm long. Each plate with 4 apical setae 18-45 μm long, 3 subapical setae 45-80 μm long, and no inner margin setae. *Ventral thickenings* (Fig. 11J2) elongate triangular. *Fringe setae* 2 pairs, 50-100 μm long. *Anal ring* 55-75 (65 ± 7) μm wide (length not measured due to orientation), with 8 setae: 2 small 100-135 μm long, others 188-215 μm long; translucent pores in 1-3 rows, each pore oval 3-5 μm in maximum diameter.

Venter: *Submarginal setae* (Fig. 11L) 12-20 μm long, slender, straight, acute; distributed as follows: 14-28 between anterior spiracular furrows, 5-9 between anterior and posterior spiracular furrows on each side, 12-23 between each posterior spiracular furrow and anal cleft. *Ventral setae* (Fig. 11M) 8-25 μm long, mostly similar to submarginal setae, setae paired and longer (35-105 μm) in median area on each segment. *Interantennal setae* 4-5 pairs, 15-175 μm long. *Prevulvar setae* 3 pairs, 110-180 μm

long. *Eyes* not detectable. *Antennae* (Fig. 11N) well developed, 8 (1 specimen with 7) segmented, 395-515 (457 ± 43) μm long, third segment longest; segment I 55-90 (72 ± 11) μm wide, 30-70 (51 ± 13) μm long. Length of segments II to VIII: 50-90 (72 ± 10) μm , 70-95 (84 ± 7) μm , 60-80 (67 ± 6) μm , 55-80 (62 ± 8) μm , 25-50 (37 ± 7) μm , 25-35 (31 ± 3) μm and 35-60 (53 ± 8) μm , respectively; number of hair-like setae: I, 3; II, 2-3; III, 0-2; IV, 0-2; V, 2-3; VI, 0; VII, 0-1; VIII, 2-3; number of fleshy setae: VI, 1; VII, 1; VIII, 5-7. *Clypeolabral shield* 150-180 (167 ± 12) μm long, 150-190 (170 ± 12) μm wide. *Labium* 55-80 (68 ± 11) μm long, 80-110 (95 ± 12) μm wide, with 4 setae 18-30 μm long on each side. *Legs* (Fig. 11O) well developed, with tibiotarsal sclerotisation and free articulation; claws without denticle; tarsal digitules slender, knobbed, 65-80 μm long; claw digitules slightly broad, equal, expanded at apex, 40-50 μm long. Leg lengths as follows:

Segments	First leg (μm)	Second leg (μm)	Third leg (μm)
Coxa	80-115 (104 ± 10)	100-130 (118 ± 8)	110-130 (124 ± 8)
Tro.+Fem.	230-300 (268 ± 21)	250-330 (292 ± 26)	250-330 (294 ± 26)
Tibia	170-215 (198 ± 13)	190-245 (213 ± 18)	190-230 (213 ± 17)
Tarsus	95-120 (104 ± 9)	100-140 (118 ± 11)	110-130 (118 ± 10)
Claw	28-32 (30 ± 1)	30-32 (31 ± 1)	30-32 (31 ± 1)
Total	665-775 (714 ± 38)	670-865 (771 ± 58)	685-845 (779 ± 58)

Anterior spiracles (Fig. 11P) each 70-100 (80 ± 11) μm long, 50-60 (51 ± 3) μm wide across atrium, atrium wider than apodeme. *Posterior spiracles* similar to anterior ones, each 70-100 (83 ± 9) μm long, 50-70 (60 ± 7) wide across atrium. Spiracles surrounded by sclerotic plate in mature specimens. *Spiracular pore bands* loose, each 1-3 pores wide, reaching beyond apodemal base of spiracles. *Spiracular pores* (Fig. 11Q) quinquelocular, 4-5 μm in diameter, 44-70 in anterior spiracular pore band, 60-95 in posterior spiracular pore band. *Multilocular pores* (Fig. 11R) 5-8 μm in diameter, 5-8 loculi, around anal area, in transverse bands on abdomen and a few beside each coxa. *Tubular ducts* of 2 types: first (Figs 2E, 11S1) with slender inner filament, numerous in

submarginal areas, duct 5-6 μm long, 3-4 μm wide, inner filament 6-12 μm long; second (Figs 2F, 11S2) with flowery tipped filament, scattered in median and submedian areas, duct 6-13 μm long, 3-4 μm wide, inner filament 15-20 μm long, 1-2 μm wide, flowery apex 3-6 μm wide. *Microducts* (Fig. 11T) scattered, 4 μm long, 2 μm wide.

Material examined

Queensland: 4 ♀, on leaves and stems of *Citrus sinensis*, Sunnybank, 23.x.1916, A.H. Benson JFD 1172,1173 (DPI); 1 ♀, Mapleton, 17.xi.1931, H. 302 (DPI); 5 ♀, on *Citrus*, Nambour, i.1933, ARB (DPI); 4 ♀, on *Citrus*, Nambour, 19.ix.1933 (DPI); 15 ♀ (2 ♀/slide except one slide with 3 ♀), on *Citrus*, Elimbah, 17.ii.1936, H. 330 (DPI); 1 ♀, on *Citrus*, Gayndah (F.W.B.), 24.v.1940, W.A.S. (DPI); 4 ♀ on one slide, on *Citrus*, Burrum, 21.ix.1950 (DPI); 11 ♀ (5+6 ♀/slide), ex *Citrus sinensis*, Grantham, 24.ix.1973, D.S. no. 3792 (DPI); 6 ♀ (2 ♀/slide), on *Hydrangea* sp., Nambour, 25.ix.1974, D.A.M. no. 3927 (DPI).

Distribution and host plants

In Australia, *P. polygonata* has been recorded only from south-east Queensland. Overseas it occurs in China, Philippines, Sri Lanka and Taiwan (Green, 1909; Morrison, 1920; Summerville, 1934; Young, 1982; Tao *et al.* 1983).

The main host plants are to citrus although it has been collected on hydrangea.

Discussion

Pulvinaria polygonata is the only species which almost always has more than three spiracular setae. It could be confused with *P. decorata* because both species possess cell-like clear areas and have some specimens with sclerotic plates surrounding the spiracles. However, *P. decorata* has some marginal setae expanded near the apex, the branches of marginal setae are much shorter and the cell-like clear areas are denser than those in *P. polygonata*. In Queensland, *P.* sp. n. has similar marginal setae to *P.*

polygonata, but *P. sp.n.* lacks submarginal tubercles and has not been recorded from citrus.

Tao *et al.* (1983, p. 87) transferred this species to *Macropulvinaria* Hodgson perhaps because the female has more than three spiracular setae. The diagnostic characters of *Macropulvinaria*, according to Hodgson (1968), are the possession of more than 5 spiracular setae, the presence of a spine-like seta at the inner margin of each anal plate and the nature of marginal setae which are stout and bidentate. However, *P. polygonata* usually only has 3 to 5 spiracular setae, the marginal setae are pointed, bifid or branched, not stout and bidentate, and the inner margin seta is absent.

Pulvinaria psidii (Maskell)

(Fig. 12)

Pulvinaria psidii Maskell, 1893, p. 223, pl. xiii, figs. 10,11; Green, 1909, p. 258, 264, pl. c, figs. 1-16; 1928, p. 24; Fernald, 1903b, p. 137; Steinweden, 1946, p. 11, fig. 11; Zimmerman, 1948, p. 333, 336, figs. 171, 172; Hodgson, 1968, p. 168-172, fig. 12; Ezzat & Hussein, 1969, p. 228; Tao, Wong & Chang, 1983, p. 85, fig. 12; Hamon & Williams, 1984; pp. 102-105, figs. 79, 80; Williams & Williams, 1988, p. 59.

Pulvinaria cupaniae Cockerell, 1893, p. 159; Fernald, 1903, p. 131; Green, 1909, p. 265 (synonymy by indication).

Pulvinaria psidii philippina Cockerell, 1905, p. 132, p. Robinson, 1917, p. 9, 11; Morrison, 1920, p. 185 (synonymy).

Pulvinaria darwiniensis Froggatt, 1915, p. 414; 1921a, p. 8. **New Synonymy**

Pulvinaria cussoniae Hall, 1932, p. 188, fig. 3; Hodgson, 1968, p. 168 (synonymy).

Pulvinaria gymnosporiae Hall, 1932, p. 189, fig. 4; Hodgson, 1968, p. 168 (synonymy).

Chloropulvinaria psidii (Maskell), Borchsenius, 1952, p. 300; 1957, p. 217-219, figs. 198, 199; Ezzat & Hussein, 1969, p. 388-390, fig. 9; Wang, 1982, p. 36-38, fig. 13; Young, 1982, p. 158; Williams, 1985a, p. 224, 228.

Common name: Green shield scale (Hamon & Williams, 1984)

Types

Lectotype of *Pulvinaria psidii*, ♀, Hawaii, (B. P. Bishop Museum, Hawaii), not examined. **Paralectotypes** (designated by C.F. Butcher, 1981): 4 first instar nymphs on one slide (NZAC), examined.

Lectotype of *P. darwiniensis* (present designation): ♀, Northern Territory, 3 labels: "*Pulvinaria darwiniensis*, Froggatt, Palmerston, N.T. Type", "564 P. Darwin." and "N. Territory, Hill, 1914, palm" (BCRI).

Diagnosis

Appearance: Adult female brightly yellow to dark yellow (but living specimens green, Hamon & Williams, 1984), shrivelled transversely, 1.9-4.0 mm long, 1.2-2.5 mm wide. Ovisac white, 0.5-1.0 mm long, about 1.4 mm wide, beneath and surrounding body, loose and without special shape or structure.

Slide-mounted adult female: Marginal setae all finely toothed; spiracle surrounded by sclerotic plate; ventral thickenings connected in middle; some ventral tubular ducts with a very long flowery tipped inner filament; dorsum with cell-like clear areas.

Description of adult female (16 slide-mounted specimens measured, Fig. 12)

Body (Fig. 12A) oval to broadly oval, 1.9-4.9 (3.3 ± 0.8) mm long, 1.1-2.6 (1.9 ± 0.4) mm wide, length 1.5-2.0 times width. **Anal cleft** 250-630 (445 ± 119) μ m long, 0.12-0.16 body length.

Margin: *Marginal setae* (Fig. 12B) 12-40 μ m long, stout, slightly curved or straight, apex expanded and finely toothed; distributed as follows: 51-80 between anterior spiracular furrows, 13-20 between anterior and posterior spiracular furrows on each side, 43-55 between each posterior spiracular furrow and anal cleft. *Spiracular setae*

(Fig. 12C) 3 in each spiracular furrow; median seta 40-60 μm long, 1.7-4.0 times as long as lateral setae, straight, tapered, bluntly pointed; lateral setae 10-30 μm long, straight, bluntly pointed. *Spiracular sclerotisation* absent.

Dorsum: *Derm* with cell-like clear areas (Fig. 12D). *Dorsal setae* (Fig. 12E) 6-8 μm long, spine-like, scattered. *Submarginal tubercles* (Fig. 12F) 9-14 around entire body, 9-13 μm in diameter, 8-13 μm deep. *Disc pores* not detectable. *Discoidal pores* (Fig. 12G) 3-4 μm in diameter, in group of 22-49 anterior to anal plates. *Tubular ducts* (Fig. 12H) sparsely scattered, duct 5-12 μm long, 3-4 μm wide, inner filament 10-15 μm long, 2 μm wide. *Microducts* (Fig. 12I) scattered, 2 μm long, 2 μm wide, inner filament 6 μm long. *Anal plates* (Fig. 12J1) triangular, 110-175 (161 ± 20) μm long, 70-100 (86 ± 9) μm wide; anterolateral margin/ ^{slightly concave,} 80-120 (103 ± 13) μm long, posterolateral margin slightly convex, 105-140 (125 ± 11) μm long. Each plate with 4 apical setae 20-25 μm long, 3 subapical setae 45-100 μm long, and no inner margin setae. *Ventral thickenings* (Fig. 12J2) elongate triangular, connected each other in middle. *Fringe setae* 2 pairs, 65-140 μm long. *Anal ring* (Fig. 12K), about 60 μm long, 45-75 (65 ± 6) μm wide, with 8 setae: 2 small 120-140 μm long, others 185-250 μm long; translucent pores in 1-2 rows, each pore 3-6 μm in maximum dimension.

Venter: *Submarginal setae* (Fig. 12L) 10-15 μm long, straight, acute; distributed as follows: 24-37 between anterior spiracular furrows, 7-11 between anterior and posterior spiracular furrows on each side, 26-34 between each posterior spiracular furrow and anal cleft. *Ventral setae* (Fig. 12M) 10-62 μm long, similar to submarginal setae. *Interantennal setae* 6-7 pairs, 15-200 μm long. *Prevulvar setae* 3 pairs, 85-193 μm long. *Eyes* broadly oval, 20-40 μm in maximum dimension. *Antennae* (Fig. 12N) well developed, 8 (a few 7) segmented, 385-530 (453 ± 39) μm long, third segment longest; segment I 57-80 (72 ± 7) μm wide, 40-80 (50 ± 12) μm long. Length of segments II to VIII: 45-75 (62 ± 10) μm , 70-150 (98 ± 13) μm , 35-60 (55 ± 8) μm , 48-70 (57 ± 8) μm , 30-40 (38 ± 4) μm , 25-40 (33 ± 5) μm and 45-58 (53 ± 4) μm , respectively; number of hair-like setae: I, 2-3; II, 3-5; III, 1-4; IV, 0-2; V, 1-3; VI, 0-1; VII, 0-1; VIII, 3-5; number of fleshy setae: VI, 1; VII, 1; VIII, 3-5. *Clypeolabral shield* 140-180

(160±14) µm long, 138-170 (151±12) µm wide. *Labium* 50-65 (54±6) µm long, 70-100 (89±10) µm wide, with 4 setae 18-32 µm long on each side. *Legs* (Fig. 12O) well developed, with tibiotarsal sclerotisation and free articulation; claws without denticle; tarsal digitules slender, knobbed, 55-75 µm long; claw digitules broad, expanded at apex, 40-52 µm long. Leg lengths as follows:

Segments	First leg (µm)	Second leg (µm)	Third leg (µm)
Coxa	80-120 (107±14)	80-130 (111±14)	90-140 (118±16)
Tro.+Fem.	205-310 (271±31)	220-330 (291±32)	220-350 (295±36)
Tibia	165-280 (232±32)	170-300 (253±38)	185-300 (256±35)
Tarsus	92-120 (112±9)	110-140 (120±10)	105-140 (122±11)
Claw	25-35 (31±3)	25-38 (33±4)	25-35 (32±3)
Total	567-860 (758±88)	607-938 (809±92)	625-965 (825±97)

Anterior spiracles (Fig. 12P) each 42-75 (63±10) µm long, 30-45 (39±5) µm wide across atrium, atrium more narrow than or about same wide as apodeme. *Posterior spiracles* similar to anterior ones, each 60-82 (75±7) µm long, 40-58 (50±6) µm wide across atrium. Spiracles surrounded by sclerotic plate in mature specimens. *Spiracular pore bands* each 1-3 pores wide, reaching apodeme of spiracles. *Spiracular pores* (Fig. 12Q) quinquelocular, 4-5 µm in diameter, 23-54 in anterior spiracular pore band, 30-53 in posterior spiracular pore band. *Multilocular pores* (Fig. 12R) 6-8 µm in diameter, 9-12 loculi, around anal area, in transverse bands on abdomen, and in group beside each coxa. *Tubular ducts* of 2 types: first (Fig. 12S1) with slender inner filament, distributed in submarginal area, duct 8-12 µm long, 3-4 µm wide, inner filament 5-10 µm long; second (Fig. 12S2, S3) with flowery tipped inner filament, 2 sizes: some (Fig. 12S2) scattered in median and submedian areas, duct 10-12 µm long, 3-4 µm wide, inner filament 13-22 µm long, 2-3 µm wide, flowery apex 4-7 µm wide; others (Fig. 12S3) with short duct and very long slender inner filament, sparsely scattered among other duct, especially in submarginal area of abdomen; duct 5-7 µm long, 3-4 µm wide, inner

filament 28-42 μm long, 1-1.5 μm wide, flowery apex 5-7 μm wide. *Microducts* (Fig. 12T) scattered over venter, more in submarginal areas, 4 μm long, 2 μm wide.

Other material examined

Australian Capital Territory: 5 ♀, ex *Alstonia scholaris*, Australian National Botanic Gardens, Canberra, 23.ix.1983, S.R. Donaldson no. 381 (ANIC).

New South Wales: 2 ♀, on *Boronia serrulata*, Hort. Res. Gosford Dist., 8.iv.1981, C.P. Lambert 243 (BCRI); 2 ♀, on *Ficus* sp., Ryde School Hort., iii.1982, submitted by McMaugh (BCRI); 2 ♀, on pigface, Mudgee, 11.vi.1984, N. Daniels (BCRI); 2 ♀, on lychee fruit, Alstonville, 4.iii.1985, N. Treverrow (BCRI). **Northern Territory:** 2 ♀, Darwin 620 (BCRI); 3 ♀, on *Anthurium triumphifolius*, Darwin, G.F. Hill (SAM).

Queensland: 5 ♀, Maroochy Horticultural Research Station, Nambour, 19.v.1988, P.J. Gullan and T.K. Qin (ANIC); 2 ♀, on leaves of *Syzygium jambos*, Mossman, 18.vii.1923, B. Pinese & K.H. Halfpapp JFD 888 (DPI); 3 ♀, on leaves of *Callistemon* sp., Kenmore, ii. 1953 JFD 1356 (DPI); 4 ♀, 2 immatures on one slide, 14 first instar nymphs (4+10/slide), on *Dodonaea triquetra*, Coolangatta, vi.1956 JFD 1540 (DPI); 3 ♀, on stems of *Chenopodium pumilio*, Kenmore, vi.1956, R.P.K. JFD 1668 (DPI); 3 ♀, on leaves of *Euphoria longan*, Walkamin, 10.viii.1983, K.H. Halfpapp JFD 885 (DPI); 2 ♀, 3 immatures, ex *Pteridium*, Dickson Way-s.side, N. Stradbroke Is., 2.ix.1983, E. Shuter (ANIC); 3 ♀, on stems of *Dianthus* sp., Thornlands, 10.ii.1986, J.F. Donaldson JFD 2725 (DPI); 7 immatures (1+2+4/slide), on violets, asters in garden (QM).

Distribution and host plants

In Australia, *P. psidii* has been collected from Canberra in the Australian Capital Territory, south-east Queensland and Darwin in the Northern Territory.

According to Williams & Williams (1988), this species is tropicopolitan extending into the temperate zone. Other countries from which *P. psidii* has been recorded include Algeria, Congo, Brazil, China, Cuba, Egypt, India, Indonesia (Java, Sumatra), Jamaica, Japan (greenhouse), Mauritius, New Caledonia, New Zealand, Philippines, Reunion,

Seychelles, South Africa, Sri Lanka, Taiwan, Uganda, United States of America (Florida, Hawaii), Western Europe (greenhouse), USSR and Zimbabwe (Green, 1909; Robinson, 1917; Takahashi, 1955; Borchsenius, 1957; Hamon & Williams, 1984; Williams & Williams, 1988).

This species occurs on a very wide range of host plants both in Australia and elsewhere (Borchsenius, 1957).

Discussion

The marginal setae of *P. psidii* are very similar to those of *P. sp. n.* However, *P. psidii* has submarginal tubercles. It may be confused with *P. decorata* because of both have submarginal tubercles and cell-like clear areas on the dorsum. Nevertheless, *P. psidii* has the ventral thickening connected at middle and some of its ventral ducts with very long inner filament.

Ferris (in Zimmerman, 1948) stressed the presence of the sclerotic plate surrounding each spiracle in *P. psidii* as a useful diagnostic character. However, Beardsley (1966) concluded that the specimens with well developed ovisac possess the sclerotic plate, whereas specimens without ovisac often lack the sclerotic plate. This was confirmed in Australian specimens.

Pulvinaria salicorniae Froggatt

(Fig. 13)

Pulvinaria salicorniae Froggatt, 1915, p. 417; 1921, p. 13.

Suggested common name: Salicornia cottony soft scale

Types

Lectotype of *Pulvinaria salicorniae* (present designation): ♀, Victoria, 3 labels: "*P. salicorniae* Froggatt, Victoria", "*Pulvinaria salicorniae* Gr [sic], Little River, Victoria" and "*Pulvinaria salicorniae* Green [sic], on *Salicornia*, Little River, Victoria, C.

French Jr" (BCRI). **Paralectotypes** (present designation): 1 ♀, same data as lectotype (BCRI); 3 ♀, remounted from Froggatt's original slides labelled "*Pulvinaria salicorniae*, n. sp. W.W.Froggatt" (BCRI)

Authorship: *Pulvinaria salicorniae* was formally described by Froggatt (1915), although Froggatt (1915, p. 418) stated that "The species was determined and given the above MS name [*Pulvinaria salicorniae*] by Mr. E. E. Green, and was given to me at his suggestion by Mr. C. French, jun." According to Article 11 (e) of the International Code of Zoological Nomenclature (International Commission of Zoological Nomenclature, 1985), the authorship should be credited to Froggatt.

Diagnosis

Appearance: Adult female dark-brown, convex, shrivelled both transversely and longitudinally, usually forming back "U" shape with high ridges in posterior area; body about 2.1 mm long, 2.1 mm wide. Ovisac white, 1.7 mm long, 1.9 mm wide, convex.

Slide-mounted adult female: Body wider than long; antennae 6 or 7-segmented; tubular ducts distributed both on dorsum and venter, but more numerous on dorsum; some spiracular pores with 3 or 4 loculi; microducts on venter very long; anal ring with 6 setae.

Description of adult female (12 slide-mounted specimens measured, Fig. 13)

Body (Fig. 13A) broadly oval, usually wider than long, 2.7-3.9 (3.4 ± 0.4) mm long, 2.6-4.0 (3.4 ± 0.5) mm wide; length 0.82-1.2 times width. **Anal cleft** 320-600 (396 ± 86) μ m long, 0.10-0.17 body length.

Margin: *Marginal setae* (Fig. 13B) 15-23 μ m long, stout, mostly slightly curved, some J-shaped; distributed as follows: 31-44 between anterior spiracular furrows, 6-16 between anterior and posterior spiracular furrows on each side, 19-21 between each posterior spiracular furrow and anal cleft. *Spiracular setae* absent. *Spiracular sclerotisation* absent.

Dorsum: *Dorsal setae* (Fig. 13E) 6-7 μm long, lanceolate, scattered.

Submarginal tubercles absent. *Disc pores* not detectable. *Discoïdal pores* (Fig. 13G) 5-10 μm in diameter, in loose band distributed in submarginal area extending from anterolateral of anal plates to level of above second coxa. *Tubular ducts* (Fig. 13H) with flowery tipped inner filament, distributed all over dorsum, numerous in band anterior to anal plate, continuously from laterior to anal plates to level of above hind coxa; duct 12-15 μm long, 3-4 μm wide, inner filament 12-15 μm long, 1.5-4 μm wide, flowery apex 3-4 μm wide. *Microducts* (Fig. 13I) scattered, 1.5-2 μm long, 1.5 μm wide, inner filament 2-3 μm long. *Anal plates* (Fig. 13J1) triangular, 160-175 (164 ± 6) μm long, 75-85 (80 ± 3) μm wide; anterolateral margin straight or slightly convex, 100-110 (101 ± 4) μm long, posterolateral margin usually concave, 115-125 μm long. Each plate with 4 apical setae 20-50 μm long, 1 subapical setae 25-53 μm long, and no inner margin setae. *Ventral thickenings* (Fig. 13J2) elongate triangular. *Fringe setae* 2 pairs, 60-80 μm long. *Anal ring* (Fig. 13K) 70-85 (79 ± 6) μm long, 70-80 (75 ± 6) μm wide, with 6 setae 165-305 μm long; translucent wax pores in 1-3 rows, each pore 4-6 in maximum dimension.

Venter: *Submarginal seate* (Fig. 13L) 6-7 μm long, slightly stout, straight; number distributed not counted due to specimens in poor condition. *Ventral setae* (Fig. 13M) 6-9 μm long, slender, scattered, mostly in median area. *Interantennal setae* 3 pairs, similar to ventral setae. *Prevulvar setae* apparently not differentiated from ventral setae. *Eyes* not seen. *Antennae* (Fig. 13N) well developed, 6 or 7-segmented, 244-278 (265 ± 12) μm long, third segment longest; segment I 65-75 (69 ± 4) μm wide, 30-60 (46 ± 10) μm long. Length of segments II to VI (if 7-segmented, III & IV measured together): 35-40 (36 ± 2) μm , 88-108 (98 ± 7) μm , 20-25 (22 ± 2) μm , 20-30 (23 ± 4) μm and 28-40 (30 ± 5) μm , respectively; number of hair-like setae: I, 2-3; II, 2-3; III, 3; IV, 0; V, 1; VI, 1-2, number of fleshy setae: IV, 1; VII, 1; VIII, 6-7. *Clypeolabral shield* 160-190 (170 ± 12) μm long, 165-180 (176 ± 7) μm wide. *Labium* 60-90 μm long, 110-123 μm wide, with 4 setae 10-18 μm long on each side. *Legs* (Fig. 13O) well developed, with tibiotarsal sclerotisation and free articulation; claws without denticle;

tarsal digitules slender, slightly knobbed, 50-75 μm long; claw digitules slender, similar to tarsal digitules, 38-50 μm long. Leg lengths as follows.

Segments	First leg (μm)	Second leg (μm)	Third leg (μm)
Coxa	85-95 (91 \pm 4)	90-110 (99 \pm 6)	100-120 (108 \pm 8)
Tro.+Fem.	230-255(244 \pm 8)	230-260(243 \pm 11)	240-260(250 \pm 9)
Tibia	150-170(161 \pm 9)	150-170(159 \pm 7)	150-170(158 \pm 8)
Tarsus	85-95 (91 \pm 4)	90-100 (96 \pm 6)	90-100 (97 \pm 5)
Claw	25-35 (30 \pm 4)	28-35 (33 \pm 3)	28-35 (32 \pm 3)
Total	590-640(618 \pm 21)	605-655(630 \pm 24)	608-660(646 \pm 2)

Anterior spiracles (Fig. 13P) each 80-95 (86 \pm 6) μm long, 62-80 (70 \pm 6) μm wide across atrium, atrium much wider than apodeme. *Posterior spiracles* similar to anterior ones, each 90-110 (103 \pm 8) μm long, 70-75 (73 \pm 4) μm wide across atrium. *Spiracular pore bands* 2-4 pores wide in most part except up to 8 pores wide at margin, extending to apodeme of spiracles. *Spiracular pores* (Fig. 13Q) usually quinquelocular, some with 3, 4 or 6 loculi, 4-7 μm in diameter, 29-50 in anterior spiracular pore band, 28-40 in posterior spiracular pore band. *Multilocular pores* (Fig. 13R) 6-10 μm in diameter, 9-12 loculi, central loculus with a slit, mostly circular, some subcircular, distributed around anal area, in transversent band in each abdominal segment, in group beside each coxa and between mouth part and first coxa. *Tubular ducts* (Fig. 13S) with flowery tipped inner filament, distributed all over venter, but more in submarginal area, duct 16-22 μm long, 3-4 μm wide, inner filament 15-20 μm long, 2-5 μm wide, flowery apex 3-7 μm wide. *Microducts* (Fig. 13T) scattered, 10-12 μm long, 2 μm wide.

Other material examined

Victoria: 8 ♀ (4 ♀ remounted^u from one slide and one slide with 4 ♀), on *Salicornia*, C. French Jr. No. 56 (BMNH).

Distribution and host plants

This endemic Australian species has been recorded only from Victoria, on glasswort.

Discussion

The marginal setae of *P. salicorniae* are similar to those of *P. mesembryanthemi* and *P. thompsoni*. The distribution of tubular ducts on both the dorsum and venter in *P. salicorniae* are similar to those in *P. dodonaeae* and *P. flavicans*. However, *P. salicorniae* is easily separated from any other pulvinariine species by the absence of spiracular setae, the body being usually wider than long, and the possession of 6 or 7-segmented antennae.

De Lotto (1979) established a monotypic genus *Mesembrya* which lacks spiracular setae (as does *P. salicorniae*) and feeds on *Mesembryanthemum* spp. *Pulvinaria salicorniae* cannot be included in *Mesembrya* because of the following differences: 6 or 7-segmented antennae, the presence of tibiotarsal sclerotisation, numerous tubular ducts on the dorsum as well as on the venter, and microducts present on the venter.

Pulvinaria thompsoni Maskell

(Fig. 14)

Pulvinaria thompsoni Maskell, 1896, p. 393, pl. xx figs 1-8; Fernald, 1903, p. 139;

Froggatt, 1915, p. 418; 1921, p. 14.

Pulvinaria paradelpha Cockerell & Lidgett (in Cockerell, 1899), 1899, pp. 15-16;

Fernald, 1903, p. 137; Froggatt, 1915, p. 417; 1921, p. 12; Williams, 1985a, p. 227. **New Synonymy**

Suggested common name: Thompson's cottony soft scale

Types

Lectotype of *Pulvinaria thompsoni* (present designation): ♀, Tasmania, labelled: "*Pulvinaria, Thompsoni*, adult female, 1895 W.W.M." (ANIC from NZAC; Maskell's original slide). **Paralectotype** (present designation): 1 ♀, same data as lectotype (NZAC; Maskell's original slide).

Maskell (1896) recorded the type specimens of *P. thompsoni* on *Dodonaea viscosa* from Hobart in Tasmania.

Lectotype of *Pulvinaria paradelpha* (present designation): ♀, remounted from slide with 2 labels: "*Pulvinaria paradelpha* Ckll & Lidg., TYPE, on *Acacia, melanoxydon*, Mts of Victoria, 9000 ft., (Lidgett)" and "presented by Prof. T.D.A. Cockerell, 1920-153" (BMNH). **Paralectotypes** (present designation): 5 ♀ (2 of them only anterior parts), remounted, same data as lectotype (BMNH).

Diagnosis

Appearance: Adult female yellow-brown to bright brown, shrivelled transversely, about 4.1 mm long, 2.1 mm wide. Ovisac white, 7.7-8.2 mm long, 2.9-3.4 mm wide, with a longitudinal furrow in middle.

Slide-mounted adult female: With a horseshoe-shaped or triangular spiracular sclerotisation in each spiracular furrow; marginal setae curved, mostly J-shaped; anal plate with 5 subapical setae.

Description of adult female (10 slide-mounted specimens measured, Fig. 14)

Body (Fig. 14A) oval, 4.6-6.3 (5.4 ± 0.5) mm long, 2.5-3.5 (3.1 ± 0.4) mm wide; length 1.5-2.0 times width. **Anal cleft** 550-900 (720 ± 104) μm long, 0.10-0.15 body length.

Margin: *Marginal setae* (Fig. 14B) 18-30 μm long, stout, curved, mostly J-shaped; distributed as follows: 51-85 between anterior spiracular furrows, 16-21 between anterior and posterior spiracular furrows on each side, 40-62 between each posterior spiracular furrow and anal cleft. *Spiracular setae* (Fig. 14C) 3 (occasionally 2,

4 or 6) in each spiracular furrow; median seta 45-60 μm long, 1.4-3.1 times as long as lateral setae, slightly curved, bluntly pointed; lateral setae straight or slightly curved, bluntly pointed, 18-38 μm long. *Spiracular sclerotisation* (Fig. 14C) horseshoe-shaped or triangular.

Dorsum: *Dorsal setae* (Fig. 14E) 7-12 μm long, spine-like, scattered.

Submarginal tubercles absent. *Disc pores* (Fig. 14G1) 3 μm in diameter, sparsely scattered. *Discoideal pores* (Fig. 14G2) 4-5 μm in diameter, in group of about 15 anterior to anal plates. *Tubular ducts* not detectable. *Microducts* (Fig. 14I) scattered, 1.5-2 μm long, 1.5 μm wide, filament 3-4 μm long. *Anal plates* (Fig. 14J1) triangular, 163-195 (182 ± 10) μm long, 70-90 (76 ± 7) μm wide; anterolateral margin straight, 90-115 (98 ± 8) μm long; posterolateral margin usually concave, 100-137 (124 ± 13) μm long. Each plate with 3 (1 specimen with 4) apical setae 20-45 μm long, 5 (1 specimen with 6) subapical setae 35-110 μm long, 1 inner marginal setae 18-40 μm long. *Ventral thickenings* (Fig. 14J2) elongate triangular. *Fringe setae* 2 pairs, 75-115 μm long. *Anal ring* (Fig. 14K) subcircular, 50-70 (61 ± 8) μm long, 58-75 (68 ± 6) μm wide, with 8 setae 150-250 μm long; translucent pores in 1-3 rows, each pore 5 μm in maximum dimension.

Venter: *Submarginal setae* (Fig. 14L) 10 μm long, slender, acute, straight or slightly curved; distributed as follows: 18-33 between anterior spiracular furrows, 5-8 between anterior and posterior spiracular furrows on each side, 15-27 between each posterior spiracular furrow and anal cleft. *Ventral setae* (Fig. 14M) 10-50 μm long, similar to submarginal setae. *Interantennal setae* 4-6 pairs, 18-85 μm long. *Eyes* not detected. *Antennae* (Fig. 14N) well developed, 7-8 (mostly 8) segmented, 363-459 (421 ± 35) μm long, third segment longest; segment I 50-100 (81 ± 15) μm wide, 50-85 (67 ± 12) μm long. Length of segments II to VIII: 50-80 (64 ± 12) μm , 100-120 (108 ± 8) μm , 30-50 (46 ± 7) μm , 30-58 (42 ± 9) μm , 28-40 (33 ± 5) μm , 25-30 (29 ± 2) μm and 45-75 (55 ± 10) μm , respectively; number of hair-like setae: I, 2-3; II, 1-3; III, 1-3; IV, 0-2; V, 1-3; VI, 1; VII, 0-1; VIII, 1-2; number of fleshy setae: VI, 1; VII, 1; VIII, 6-8. *Clypeolabral shield* 150-190 (173 ± 10) μm long, 160-190 (177 ± 14) μm wide. *Labium* 65-80 (69 ± 6) μm long, 90-140 (112 ± 14) μm wide, with 4 setae 15-38 μm long on each

side. *Legs* (Fig. 14O) well developed, with tibiotarsal sclerotisation and free articulation; claws without denticle; tarsal digitules slender, slightly knobbed. 65-88 μm long; claw digitules broad, expanded at apex, 40-60 μm long. Leg lengths as follows.

Segments	First leg (μm)	Second leg (μm)	Third leg (μm)
Coxa	80-110 (93 \pm 8)	90-120 (105 \pm 9)	95-130 (112 \pm 9)
Tro.+Fem.	220-300 (263 \pm 21)	245-300 (269 \pm 17)	250-300 (269 \pm 15)
Tibia	150-210 (171 \pm 19)	150-215 (183 \pm 21)	160-220 (187 \pm 17)
Tarsus	80-110 (94 \pm 9)	95-110 (107 \pm 7)	100-120 (108 \pm 6)
Claw	23-28 (26 \pm 2)	25-35 (28 \pm 4)	25-35 (28 \pm 3)
Total	593-757 (649 \pm 49)	620-785 (698 \pm 48)	632-805 (705 \pm 48)

Anterior spiracles (Fig. 14P) each 70-110 (86 \pm 10) μm long, 55-70 (65 \pm 5) μm wide across atrium, atrium slightly wider than or same wide as apodeme. *Posterior spiracles* each 80-115 (88 \pm 28) μm long, 70-80 (75 \pm 6) μm wide across atrium. *Spiracular pore bands* 1-2 (mostly 2) pores wide, extending to spiracular apodemal base. *Spiracular pores* (Fig. 14Q) quinquelocular, 5 μm in diameter, 33-52 in anterior spiracular pore band, 35-59 in posterior spiracular pore band. *Multilocular pores* (Fig. 14R) 6-8 μm in diameter, 9-11 loculi, around anal area and in transverse band on posterior abdominal segments, scattered in submedian area of abdomen. *Tubular ducts* (Fig. 14S1, S2) with flowery tipped inner filament, distributed over venter, duct 12-25 μm long, 3 μm wide, inner filament 9-15 μm long, 1-2 μm wide, flowery apex 2-3 μm wide. *Microducts* (Fig. 14T) scattered, bulbous, 3-5 μm long, 1-1.5 μm wide.

Other material examined

Australian Capital Territory: 6 ♀, ex *Daviesia mimosoides*, the Australian National Botanic Gardens, Black Mountain, Canberra, 27.xi.1981, S. Donaldson no. 206 (ANIC); 3 ♀, ex *Daviesia* sp., off Dryandra St, O'Connor, Canberra, 12.xii.1987, P.J. Gullan (ANIC). **Tasmania:** 1 posterior part of ♀, ex dry material in rectangular

box #296" (NZAC). **Victoria:** 1 ♀, from *Acacia melanoxydon*, J. Lidgett (BMNH; 1940, 180).

Distribution and host plants

This Australian species is known from Hobart in Tasmania, Victoria and Canberra in the Australian Capital Territory.

Known host-plants genera are *Acacia*, *Daviesia* and *Dodonaea*.

Discussion

Pulvinaria thompsoni has spiracular sclerotisation like that in *P. dodonaeae* and *P. flavicans*, but the latter two species are very different in the distribution of tubular ducts, shape and size of spiracular sclerotisation, length and number of subapical setae and others. The marginal setae of *P. thompsoni* are similar to those of *P. mesembryanthemi* and *P. salicorniae*, but *P. thompsoni* has spiracular sclerotisation and completely lacks tubular ducts on the dorsum.

Pulvinaria sp. n.

(Fig. 15)

A name has not been given to this species yet because its taxonomic status is still being checked by Dr Watson of C. A. B. International Institute of Entomology in England. A name will be attached to this species when the present work is published.

Types

Holotype: ♀ (encircled in black on slide), Queensland, ex *Physalis peruviana*, Brisbane, v.1943 (QM). **Paratypes:** 1 ♀, on same slide as holotype (QM); 3 ♀ on one slide, same data as holotype (DPI); 17 ♀ (1♀/slide except one slide with 9 ♀), on *Physalis peruviana*, Brisbane, i.39, ARBH 252 (DPI).

Diagnosis

Appearance: Adult female shrivelled, brown or grey-brown, 1.0-1.5 mm long, 1.0-1.5 mm wide. Ovisac white, 2.0-6.0 mm long, 1.5-3.0 mm wide, convex.

Slide-mounted adult female: Marginal setae with apex finely frayed or bluntly pointed; 4 apical setae on anal plates; ventral thickenings narrow; submarginal tubercles absent; subdiscal seta absent; tubular ducts absent ventrally in submarginal area of head and thorax.

Description of adult female (17 slide-mounted specimens measured, Fig. 15)

Body (Fig. 15A) oval to broadly oval, 1.5-3.5 (2.5 ± 0.6) mm long, 1.2-2.5 (1.9 ± 0.5) mm wide, length 1.2-1.6 times width. Dorsum convex and larger than venter. *Anal cleft* 220-420 (324 ± 73) μm long, 0.11-0.15 body length.

Margin: Marginal setae (Fig. 15B) 20-75 μm long, slender, straight or curved, some bluntly pointed, some bifid or fimbriate; distributed as follows: 28-47 between anterior spiracular furrows, 10-15 between anterior and posterior spiracular furrows on each side, 24-42 between each posterior spiracular furrow and anal cleft. *Spiracular setae* (Fig. 15C) 3 in each spiracular furrow; median seta 53-75 μm long, 1.4-4.0 times as long as lateral setae, straight or slightly curved, bluntly pointed; lateral setae 15-40 μm long, straight, bluntly pointed. *Spiracular sclerotisation* absent.

Dorsum: Dorsal setae (Fig. 15E) 8-12 μm long, spine-like, scattered.

Submarginal tubercles absent. *Disc pores* not detectable. *Discoidal pores* (Fig. 15G) 2-3 μm in diameter, in group of 4-12 in median area anterior to anal plates. *Tubular ducts* (Fig. 15H) scattered; duct 7-9 μm long, 2.5-3 μm wide, inner filament 6-7 μm long. *Microducts* (Fig. 15I) scattered; 2 μm long, 2 μm wide, inner filament 4-10 μm long. *Anal plates* (Fig. 15J1) each triangular, 130-165 (143 ± 11) μm long, 70-95 (83 ± 8) μm wide; anterolateral margin concave, 90-120 (103 ± 10) μm long, posterolateral margin convex, 100-120 (109 ± 6) μm long. Each plate with 4 apical setae 20-35 μm long, 3 subapical setae 45-75 μm long, and no inner margin setae. *Ventral thickenings* (Fig. 15J2) narrow. *Fringe setae* 2 pairs, 55-105 μm long. *Anal ring* 65-80 (72 ± 6) μm wide,

with 8 setae 70-185 μm long; translucent pores in 1-3 rows, each pore 5-6 μm in maximum dimension.

Venter: *Submarginal setae* (Fig. 15L) 10-15 μm long, slender, straight, acute; distributed as follows: 17-22 between anterior spiracular furrows, 5-7 between anterior and posterior spiracular furrows on each side, 14-21 between each posterior spiracular furrow and anal cleft. *Ventral setae* (Fig. 15M) 10-45 μm long, similar to submarginal setae, paired and longer in median area on each segment. *Interantennal setae* 4-5 pairs, 10-120 μm long. *Prevulvar setae* 3 pairs, 80-125 μm long. *Eyes* not detectable.

Antennae (Fig. 15N) well developed, 8 (occasionally 6 or 7) segmented, 295-370 (332 \pm 26) μm long, third segment longest; segment I 55-75 (67 \pm 7) μm wide, 35-45 (39 \pm 4) μm long. Length of segments II to VIII: 40-65 (51 \pm 8) μm , 55-70 (64 \pm 6) μm , 30-45 (40 \pm 4) μm , 38-55 (43 \pm 7) μm , 20-30 (26 \pm 3) μm , 18-30 (24 \pm 4) μm and 35-50 (42 \pm 5) μm , respectively; number of hair-like setae: I, 3; II, 2-3; III, 0-1; IV, 0-1; V, 2-3; VI, 0; VII, 1; VIII, 2-3; number of fleshy setae: VI, 1; VII, 1; VIII, 6-8.

Clypeolabral shield 130-150 (144 \pm 8) μm long, 135-170 (153 \pm 10) μm wide. **Labium** 55-75 (63 \pm 7) μm long, 95-120 (103 \pm 9) μm wide, with 4 setae 22-35 μm long on each side. **Legs** (Fig. 15O) well developed, with tibiotarsal sclerotisation and free articulation; claws without denticle; tarsal digitules slender, knobbed, 50-75 μm long; claw digitules broad, equal, expanded at apex, 32-45 μm long. Leg lengths as follows:

Segments	First leg (μm)	Second leg (μm)	Third leg (μm)
Coxa	70-90(81 \pm 6)	75-110(92 \pm 11)	80-110(94 \pm 12)
Tro.+Fem.	190-240(214 \pm 19)	200-260(226 \pm 22)	205-255(229 \pm 18)
Tibia	120-180(147 \pm 18)	135-180(158 \pm 17)	138-180(160 \pm 13)
Tarsus	80-100(93 \pm 8)	85-105(95 \pm 7)	85-100(96 \pm 6)
Claw	25-30(28 \pm 3)	25-32(29 \pm 3)	25-30(29 \pm 2)
Total	490-640(563 \pm 48)	520-675(600 \pm 57)	536-675(607 \pm 48)

Anterior spiracles (Fig. 15P) each 60-80 (70 \pm 9) μm long, 40-50 (48 \pm 4) μm wide across atrium, atrium usually narrower than apodeme. **Posterior spiracles** similar to anterior

ones, each 60-85 (73 ± 8) μm long, 45-55 (50 ± 3) wide across atrium. *Spiracular pore bands* each 1-2 pores wide, beyond apodemal base of spiracles. *Spiracular pores* (Fig. 15Q) quinquelocular, 4-5 μm in diameter, 27-45 pores in anterior spiracular pore band, 30-51 in posterior spiracular pore band. *Multilocular pores* (Fig. 15R) 6-8 μm in diameter, 6-8 loculi, around anal area, in transverse bands on each of posterior 4 abdominal segments, and 2 on each of anterior abdominal segments and in group beside each hind coxa. *Tubular ducts* of 2 types: first (Fig. 15S1) with slender inner filament, numerous in submarginal areas of abdomen, duct 9-14 μm long, 2-3 μm wide, inner filament 8-14 μm long; second (Fig. 15S2, S3) with flowery tipped inner filament of 2 thicknesses: one (Fig. 15S2) with slender inner filament, mostly distributed in median area of posterior 3 abdominal segments and submedian area of abdomen, duct 6-18 μm long, 3-4 μm wide, inner filament 13-22 μm long, 1-1.5 μm wide (wider toward flowery apex), flowery apex 2-6 μm wide; other (Fig. 15S3) with broader inner filament, ducts 10-18 μm long, 3-4 μm wide, inner filament 15-22 μm long, 2-3 μm wide, flowery apex 4-6 μm wide. *Microducts* (Fig. 15T) scattered, 3-4 μm long, 1.5-2 μm wide.

Other material examined

Northern Territory: 10 ♀ (5 ♀/slide), Darwin, G.F.Hill 605, J.B.E.B2 (BMNH). **Queensland:** 3 ♀ on one slide, ex *Lantana*, Brisbane, 9.ii.1940, WAS (DPI); 8 ♀ on one slide, ex *Dianthus caryophyllus*, Ipswich, 17.v.1940, WAS (DPI); 8 ♀ (2 ♀/slide except one slide with 1 ♀, another with 3 ♀), ex *Dahlia pinnata*, Brisbane, 2.iv.1941, WAS (DPI); 3 ♀ on one slide, ex small weed, Brisbane, 1.v.1941, WAS (DPI); 1 ♀, ex *Capsicum frutescens*, 17.iii.1943 (DPI); 1 ♀, ex *Physalis peruviana*, Brisbane, 1.iv.1947 (DPI); 7 ♀ on one slide, ex *Lantana*, Rockhampton, 1.iv.1947 (DPI); 7 ♀ (3+4 ♀/slide), ex *Physalis peruviana*, Brisbane, iv.1947 (DPI); 3 ♀, ex stems of *Lantana camara*, Kenmore, 1.xi.1953, R.P.K. JFD 1414 (DPI); 2 ♀ on one slide, 4 immature (2 ♀/slide), ex stems of *Alternanthera* sp., Surfers Paradise, vi.1956, JFD 1536 (DPI); 10 ♀, ex *Malpighia glabra*, Kameranga, i.1962, GWS (DPI); 3 ♀, ex stems, JFD 1187 (DPI); 1 immature, 3 first instar nymphs all on one slide, on *Adiantum* sp., 1791

(QM); 5 ♀ (2+3♀/slide), 1 immature and 4 first instar nymphs on one slide, Bunya Mt., 3500 ft, H. Hacker, 1802 (QM). **Papua New Guinea:** 1 ♀, on *Psidium guajava*, Christensen Research Institute, 8 km N of Madang, 1.vi.1989, P. J. Gullan (ANIC).

Distribution and host plants

Specimens of *Pulvinaria* sp. n. have been collected from south-east Queensland and Darwin in the Northern Territory. It may have been introduced into Australia because most of its host plants are not native to Australia. It also has been collected from Papua New Guinea.

Known host-plant genera are *Alternanthera*, *Adiantum*, *Capsicum*, *Dahlia*, *Dianthus*, *Lantana*, *Malpighia*, *Physalis* and *Psidium*.

Discussion

Pulvinaria sp. n. is closer to *P. hydrangeae* than to any other *Pulvinaria* species found in Australia. However, *P.* sp. n. lacks subdiscal setae, and the ventral tubular ducts are less numerous than in *P. hydrangeae* and are absent from the submarginal area of the head and thorax. The absence of submarginal tubercles distinguishes *P.* sp. n. from *P. decorata*, *P. floccifera*, *P. phariae*, *P. polygonata* and *P. psidii*.

Pulvinaria sp. n. is very similar to a North American species, *P. peninsularis* Ferris (1921). The main differences are: 4 apical setae on the anal plates of *P.* sp. n., 3 on those of *P. peninsularis*; 8 or less antennal segments in *P.* sp. n., 9 segmented (Steinweden, 1946, Fig. 8) in *P. peninsularis*; claw digitules broader in *P.* sp. n., slender (Steinweden, 1946, Fig. 8) in *P. peninsularis*; submarginal tubercles completely absent in *P.* sp. n., but present in some specimens of *P. peninsularis*; and the shape of the marginal setae, especially the frayed ones seems different in the 2 species.

Intraspecific variation: The spiracles are longer and more slender in specimens from the Northern Territory than in specimens from Queensland.

5. 6. Uncertain names

Pulvinaria daveyi Froggatt **Nomen dubium**

Pulvinaria daveyi Froggatt, 1923, p. 162.

The type specimens of *Pulvinaria daveyi* cannot be located in BCRI where Froggatt's specimens were deposited. Froggatt (1923, p. 162) recorded that it was "collected near Bright, Victoria, by Mr. H. W. Davey upon the foliage of the cypress pine (*Callitris* sp.)."

From the original description, it is very likely that *P. daveyi* is a synonym of *P. maskelli*.

Pulvinaria maskelli var. *viminariae* Fuller **Nomen dubium**

Pulvinaria maskelli var. *viminariae* Fuller, 1899, p. 458; Fernald, 1903, p. 136.

The type specimens of *Pulvinaria maskelli* var. *viminariae* Fuller cannot be located. Fuller was from Natal, South Africa, and described this variety when he was at Perth, Western Australia. *Pulvinaria maskelli* var. *viminariae* was collected on *Viminaria denudata* at Pinjarrah and *Hakea ilicifolia* at Bunbury. Fuller (1899, p. 485) noted that: "In its anatomical details, the ♀ resembles *P. nutysiae*, Maskell.", therefore it is probably a synonym of *P. maskelli*.

CHAPTER 6

GENERAL DISCUSSION AND CONCLUSION

6. 1. Taxonomy and phylogeny of the world genera

There are 26 genera in the Pulvinariini (see Appendix B). Some have been restudied subsequent to original description and accepted by recent authors. Others have never been restudied. Many are monotypic. The situation is as follows:

1. *Pulvinaria*: Following the establishment of this genus in 1866, the species referred to it increased dramatically: 24 species (Cockerell, 1893), 62 species (Fernald, 1903) and 118 species (Steinweden, 1946). Borchsenius (1952, 1953, 1957) then distributed the species amongst several genera and retained 26 Palaearctic species in *Pulvinaria*. The generic positions for the non-Palaearctic species were not established by Borchsenius (1957) due to unavailability of material. Many of the modern revisionary works (e.g. Hodgson, 1968; De Lotto, 1979; Young, 1982, Tao *et al.*, 1983) seem to have followed the trend established by Borchsenius, namely separating new genera from *Pulvinaria* so that it contains many fewer species.

2. Seven genera have been restudied and accepted by later authors (accepting authors in parentheses): *Acanthopulvinaria* (Ezzat & Hussein, 1969), *Lagosinia* (Hodgson, 1968), *Macropulvinaria* (Tao *et al.*, 1983), *Philephedra* (Nakahara & Gill, 1985), *Protopulvinaria* (Williams & Kosztarab, 1972; Hamon & Williams, 1984; Gill, 1988), *Rhizopulvinaria* (Canard, 1967; Tereznikova, 1981; Kosztarab & Kozár, 1988) and *Takahashia* (De Lotto, 1968).

3. Three genera have been restudied and accepted by some authors but not by others. These genera were all erected by Borchsenius: *Chloropulvinaria* (accepted: Kosztarab & Kozár, 1988; not accepted: Hamon & Williams, 1984; Gill, 1988), *Eupulvinaria* (accepted: Canard, 1965; not accepted: Young, 1982; Danzig, 1988 (in lit.)), *Pulvinariella* (accepted: De Lotto, 1979; not accepted: Gill, 1988).

4. Thirteen genera remain monotypic and of these nine have been restudied by or were originally established by modern authors (restudying or establishing authors in

parentheses): *Anapulvinaria* (Tereznikova, 1981), *Anopulvinaria* (Fonseca, 1972), *Lectopulvinaria* (Kanda, 1960), *Megapulvinaria* (Young, 1982), *Mesembryna* (De Lotto, 1979), *Metapulvinaria* (Nakahara & Gill, 1985), *Neopulvinaria* (Canard, 1965), *Phyllostroma* (Giliomee, 1967, male study; Kosztarab & Kozár, 1988), and Genus B (Giliomee, 1967, male study). Four of them have not been restudied: *Allopulvinaria*, *Pendularia*, *Pulvinarisca* and *Pulvinella*.

5. *Tectopulvinaria* contains two species and has not been restudied by modern authors. *Saccharipulvinaria* was established by Tao *et al.* (1983) and includes more than one species.

Williams (1982) stated that there is such a pressing need for a revision of *Pulvinaria* that any splitting of the genus without a true knowledge of affinities would lead to innumerable difficulties later. This view seems to be shared by Williams & Kosztarab (1972), Hamon & Williams (1984) and Gill (1988), because they have not accepted Borchsenius' (1957) generic concepts in their works on the North American species.

So far, the classification of the Pulvinariini has been based entirely on characters of the adult females, which are neotenic. For practical purposes, this is reasonable because adult females are almost always available. However, a system based solely on the adult females is unsatisfactory because it utilises only a part of the potentially available information (Boratynski & Davies, 1971) and, moreover, scale insects from widely different lineages appear to have invaded similar habitats and developed convergent morphologies (Miller & Kosztarab, 1979).

The immature stages, especially the first instar nymphs, are poorly studied in the Pulvinariini. Although a few have been adequately described (e.g. Phillips, 1962; Gill, 1979), they have not been used for classification. The morphology of the mobile first instar nymphs is not influenced by the host plants and may be useful for determining relationships between closely related taxa.

The adult males of the Pulvinariini have not been used in classification except for three species described by Giliomee (1967). If the males of all species of Pulvinariini

were to be studied, the generic classification of the tribe would probably change markedly. Giliomee (1967) has clearly demonstrated that there are some differences between the system based entirely on the adult females and that based entirely on the adult males in the family Coccidae.

The phylogeny of the Pulvinariini has not been studied. Its relationship with other taxa was mentioned by several authors in the early literature. Cockerell (1893) was apparently the first author to discuss the evolution of the group and the relationship between *Pulvinaria* (all Pulvinariini still in this genus) and other taxa. He stated that *Pulvinaria* is practically identical with '*Lecanium*' (this is now invalid and species originally placed in *Lecanium* are distributed amongst several genera) before the formation of the ovisac, and that *Pulvinaria* had evolved from the flat type of '*Lecanium*', which may be regarded as the most primitive form of soft scale. He believed that the evolution of these scale insects had been guided by the supreme necessity for protecting eggs. Newstead (1903, see Ramakrishna Ayyar, 1925) and Green (1909) agreed that all stages of *Pulvinaria* species are inseparable from those of '*Lecanium*' until the period of oviposition. Nevertheless, Green (1928) noticed that the typical *Pulvinaria* species have tibiotarsal sclerotisation and free articulation, while Steinweden (1929) found that typical '*Lecanium*' species lack the above characters and therefore *Pulvinaria* became morphologically distinguishable from '*Lecanium*'.

The Pulvinariini appear to be polyphyletic for two reasons.

First, the group is defined mainly by the possession of an ovisac behind and beneath the body of the adult female. Most of the features given in Borchsenius' (1957) diagnosis of the tribe occur in other coccid groups and cannot be used to distinguish the Pulvinariini from other taxa. Steinweden (1929, 1946) stated that '*Lecanium*' has the same type of tubular ducts present in the same position as in *Pulvinaria*, but it does not possess an ovisac, and therefore the difference between *Pulvinaria* and '*Lecanium*' is due to some physiological difference in the secretion of wax by the glands of the tubular ducts. De Lotto (1964) supported Steinweden's statement and further pointed out that the presence or absence of an ovisac should be retained as a feature of specific significance

only. The fine structure of the wax glands of tubular ducts in the Pulvinariini has not been studied except for those of *P. regalis*, described by Foldi & Pearce (1985), who concluded that the tubular ducts produce wax forming the ovisac. Waku & Foldi (1984, p. 320) stated that '... the wax gland morphology can be regarded as an effective criterion and should be included as important phenotypes in the classification of the scale insects.' Study of the wax-producing glands, such as the work of Foldi & Pearce (1985) can probably help elucidate the relationship between the genera within the Pulvinariini and between Pulvinariini and other taxa.

Second, some of the genera placed in the Pulvinariini by Borchsenius (1957) have been shown to belong to different groups (of subfamily rank) in the family Coccidae, using morphological characters of both adult females (Steinweden, 1929) and adult males (Giliomee, 1967).

6. 2. Distribution

Pulvinariine species have been described from all over the world. Endemic species have been recorded from most zoogeographical regions. For example, Steinweden (1946) claimed that there are four native species of *Pulvinaria* in North America; eight species of *Philephedra* are also endemic to North America (Nakahara & Gill, 1985); De Lotto (1979) concluded that the origin of *P. mesembryanthemi* was somewhere in the southern tip of the African continent; Williams (1982) suggested that *P. iceryi* and its allies, which all feed on sugar-cane and other grasses, originated in Africa.

Many species are widely distributed and the country of origin is often difficult to determine. Association with a native host plant is generally used as evidence for the natural distribution. Following this approach, of the 13 Australian species studied here, five species are considered to be native: *P. dodonaeae*, *P. flavicans*, *P. maskelli*, *P. salicorniae* and *P. thompsoni*; one species, *P. psidii*, is tropicopolitan extending to the temperate zone (Williams & Williams, 1988); six species are introduced: *P. decorata*, *P. elongata*, *P. floccifera*, *P. hydrangeae*, *P. mesembryanthemi* and *P. polygonata*; and the

origin of *P. sp. n.* is unknown, although several genera of its host plants are native to South America.

6. 3. General conclusions and recommendations for future study

The present revision has provided the first detailed study of the Australian pulvinariine species based on morphological characters of the adult females. Thirteen species have been recognised and ten new synonyms have been proposed. The Australian species now can be identified using a key based on adult females and the morphological features of the adult females have been described in detail. A brief literature review of the world Pulvinariini has been included.

Some new and unusual morphological features have been described in the Pulvinariini. These include the following: spiracular sclerotisations in three species, submarginal chambered ducts of *P. dodonaeae*, the large-based marginal setae and reticulated anal plates of *P. maskelli*, which also has unique microducts on the dorsum, absence of spiracular setae in *P. salicorniae* and lack of tibiotarsal sclerotisation and free articulation in *P. flavicans*, which has peculiar multilocular pores.

The above autapomorphies have raised questions about the taxonomic positions of the above four Australian species which do not satisfactorily fit into any existing genera of Pulvinariini. These four species may require erection of new genera but these have to await phylogenetic revision of the world Pulvinariini. Pending the world revision one can say that the tribe Pulvinariini appears to be polyphyletic, and the existing generic framework is inadequate, and some generic concepts are still controversial.

Two aspects of the pulvinariine study need to be undertaken in Australia. First, detailed descriptions and illustrations of the immature stages, especially the first instar nymphs, and the adult males, are needed to provide independent sets of morphological data of phylogenetic importance. With these data, knowledge of at least Australian Pulvinariini could be broadened, and the taxonomic positions of the various species may be solved. Second, observations are needed on the biology of economically important species. Such data are needed for better control of the pest species.

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APPENDIX A

Published descriptions of the first instar nymphs (FIRST), male puparia (PUPA.) and adult males (MALE) of species of Pulvinariini

(The names are listed as given by the original authors. Synonyms are indented.

Abbreviations: *Chlorop.* = *Chloropulvinaria*, *Eup.* = *Eupulvinaria*, *P.* = *Pulvinaria*,

Rhizop. = *Rhizopulvinaria*, √ = described, √* = every immature stage described)

SPECIES	FIRST	PUPA.	MALE	REFERENCES
<i>Chlorop. aurantii</i>			√	Borchsenius, 1957
<i>Eup. hydrangeae</i>		√		Canard, 1969
<i>Phyllostroma myrtilli</i>			√	Gillimee, 1967;
		√		Borchsenius, 1957
<i>P. ? betulae</i>			√	Gillimee, 1967
<i>P. acericola</i>			√	Gillimee, 1967
<i>P. antigoni</i>		√		Green, 1907
<i>P. camelicola</i>			√	Signoret, 1873
<i>P. cellulosa</i>	√			Summerville, 1934
<i>P. citricola</i>	√			Kuwana, 1914
<i>P. delottoi</i>	√*			Gill, 1979
<i>P. dodonaeae</i>	√	√		Maskell, 1893
<i>P. ellesmerensis</i>	√*			Richards, 1964
<i>P. elongata</i>	√			Newstead, 1917
<i>P. ephedrae</i>		√		Cockerell, 1898
<i>P. ericae</i>			√	Löw, 1883
<i>P. flavescens</i>			√	Quintana, 1956
<i>P. flavicans</i>	√			Maskell, 1889
<i>P. contexta</i>	√			Froggatt, 1915;

(Appendix A, continued)

<i>P. floccifera</i>			✓	Brain, 1920
<i>Chlorop. floccifera</i>	✓			Khadzhibeylic, 1978
<i>P. idesia</i>	✓			Kuwana, 1914
<i>P. innumerabilis</i>	✓*			Phillips, 1962
<i>P. jacksoni</i>		✓		Newstead, 1908
			✓	Brain, 1920
<i>P. lutea</i>	✓			Cockerell, 1893a
<i>P. maskelli</i>	✓	✓	✓	Olliff, 1892
		✓		Froggatt, 1915
<i>Signoretia atriplicis</i>	✓		✓	Maskell, 1891
<i>P. nuytsiae</i>	✓	✓		Maskell, 1897
<i>P. maskelli spinosior</i>	✓			Maskell, 1894
<i>P. maxima</i>	✓	✓	✓	Ramakrishna Ayyar, 1925
<i>P. mesembryanthemi</i>		✓	✓	Brain, 1920
		✓	✓	Pesson, 1941
<i>P. nishigahaharae</i>	✓			Borchsenius, 1957
<i>P. obscura</i>	✓			Newstead, 1894
<i>P. occidentalis</i>	✓			Steinweden, 1929
<i>P. okitsuensis</i>	✓			Kuwana, 1914
<i>P. ornata</i>		✓		Froggatt, 1921a
<i>P. phaiae</i>	✓	✓	✓	Lull, 1899
<i>P. photiniae</i>	✓			Kuwana, 1914
<i>P. populi</i>		✓	✓	Borchsenius, 1957
<i>P. psidii</i>	✓			Maskell, 1893
	✓			Green, 1909
	✓			Brain, 1920

(Appendix A, continued)

<i>P. rhois</i>		✓		Ehrhorn, 1898
<i>P. ribesiae</i>	✓			Paramonova & Saakyan- -Baranova, 1984
<i>P. serpentina</i>		✓		Balachowsky, 1929
<i>P. tessellata</i>		✓	✓	Green, 1909
<i>P. thespesiae</i>		✓		Green, 1909
<i>P. thompsoni</i>	✓	✓		Maskell, 1896
<i>P. paradelpha</i>		✓		Cockerell, 1899
<i>P. tremulae</i>	✓			Signoret, 1873
<i>P. urbicola</i>	✓			Cockerell, 1893
<i>P. vitis</i>	✓		✓	Signoret, 1873
	✓			Steinweden, 1929
	✓*			Phillips, 1962
<i>Rhizop. arenaria</i>		✓	✓	Canard, 1967a
<i>Rhizop. artemisiae</i>		✓		Canard, 1968

APPENDIX B

Checklist of the genera of the tribe Pulvinariini

Pulvinariini Ashmead

Pulvinariini Ashmead, 1891, p. 98; Borchsenius, 1957, p. 202; Nakahara & Gill, 1985, p. 4; Kosztarab & Kozár, 1988, p. 175.

Type genus

Pulvinaria Targioni-Tozzetti, 1866, p. 146.

Type species: *Coccus vitis* Linnaeus, 1758, by original designation and monotypy.

Other genera

Acanthopulvinaria Borchsenius, 1952, p. 297, 301.

Type species: *Pulvinaria orientalis* Nassanov, 1908, by original designation.

Allopulvinaria Brain, 1920, p. 16.

Type species: *Allopulvinaria subterranea* Brain, 1920, by original designation and monotypy.

Anapulvinaria Borchsenius, 1952, p. 300.

Type species: *Pulvinaria pistaciae* Bodenheimer, 1926, by original designation and monotypy.

Anopulvinaria Fonseca, 1972, p. 195.

Type species: *Anopulvinaria cephalocarinata* Fonseca, 1972, by original designation and monotypy.

Chloropulvinaria Borchsenius, 1952, p. 299-300.

Type species: *Coccus floccifera* Westwood, 1870, by original designation.

Eupulvinaria Borchsenius, 1953, p. 288.

Type species: *Eupulvinaria peregrina* Borchsenius, 1953, by original designation.

Lagosinia Cockerell, 1899b, p. 332; Hodgson, 1968, p. 142.

Type species: *Lecanium strachani* Cockerell, 1898, by original designation and monotypy.

Leptopulvinaria Kanda, 1960, p. 118

Type species: *Leptopulvinaria elaeocarpi* Kanda, 1960, by original designation and monotypy.

Macropulvinaria Hodgson, 1968, 155.

Type species: *Pulvinaria jacksoni* Newstead, 1908, by original designation.

Megapulvinaria Young, 1982, p. 162.

Type species: *Pulvinaria maxima* Green, 1904, by original designation and monotypy.

Mesembryna De Lotto, 1979, p. 245.

Type species: *Mesembryna fasciata* De Lotto, 1979, by original designation and monotypy.

Metapulvinaria Nakahara & Gill, 1985, p. 36-37.

Type species: *Lichtensia lycii* Cockerell, 1895a, by original designation and monotypy.

Neopulvinaria Hadzibejli, 1955, p. 232.

Type species: *Neopulvinaria imertina* Hadzibejli, 1955, by original designation and monotypy.

Pendularia Fonseca, 1927, p. 268; Nakahara & Gill, 1985, p. 4.

Type species: *Pendularia pendens* Fonseca, 1927, by original designation and monotypy.

Philephedra Cockerell, 1898, p. 24; 1899b, p. 331; Nakahara & Gill, 1985, p. 5.

Type species: *Pulvinaria* (*Philephedra*) *ephedrae* Cockerell, 1898, by original designation and monotypy.

Phyllostroma Sulc, 1942, p. 5.

Type species: (*Pulvinaria erieae* Löw, 1883) = *Lecanium myrtilli*

Kaltenbach, 1874, by original designation and monotypy.

Protopulvinaria Cockerell, 1894, p. 309; 1899b, p. 330.

Type species: *Pulvinaria* (*Protopulvinaria*) *pyriformis* Cockerell, 1894, by original designation and monotypy.

Pulvinariella Borchsenius, 1953, p. 287; De Lotto, 1979, p. 254.

Type species: *Coccus mesembryanthemi* Vallot, 1829, by original designation and monotypy.

Pulvinarisca Borchsenius, 1953, p. 288.

Type species: *Pulvinaria serpentina* Balachowsky, 1929, by original designation and monotypy.

Pulvinella Hempel, 1899, p. 132; Cockerell, 1899b, p. 331.

Type species: *Pulvinaria* (*Pulvinella*) *pulchella* Hempel, 1899, by original designation and monotypy.

Rhizopulvinaria Borchsenius, 1952, p. 296, 297, 301.

Type species: *Rhizopulvinaria virgulata* Borchsenius, 1952, by original designation.

Saccharipulvinaria Tao, Wong & Chang, 1983, p. 85.

Type species: *Coccus iceryi* Signoret, 1868, by original designation; however, Kosztarab, Ben-Dov & Kosztarab (1986) noticed that, in their further discussion, Tao *et al.* actually refer to *Lecanium iceryi* Signoret, 1869, rather than *Coccus iceryi*.

Takahashia Cockerell, 1896b, p. 20; 1899b, p. 331; De Lotto, 1968, p. 97.

Type species: *Pulvinaria* (*Takahashia*) *japonica* Cockerell, 1896, by original designation and monotypy.

Tectopulvinaria Hempel, 1900, p. 482 (in Cockerell, 1899b, p. 331, footnotes, nomen nudum).

Type species: *Tectopulvinaria albata* Hempel, 1900, by original designation and monotypy.

Genus B. sp. (near *Pulvinaria*), Giliomee, 1967, p. 96.

(Giliomee described the adult male of Genus B. sp., but he did not give a generic or specific name nor designate a type species).

FIGURE LEGENDS

Fig. 1. General morphology of the adult female of Australian pulvinariine species. **A.** Body derm (dorsum on left, venter on right); **B.** Marginal setae: 1. pointed, 2. expanded near apex, 3. frayed, 4. bluntly pointed, 5. truncate, 6. with large base; **C.** Spiracular setae: 1. three spiracular setae, 2. three spiracular setae associated with spiracular sclerotisation, 3. one spiracular seta associated with spiracular sclerotisation; **D.** Cell-like clear areas; **E.** Dorsal setae; **F1.** Submarginal tubercle; **F2.** Submarginal duct; **G1.** Dorsal disc pore; **G2.** Discoidal pore; **H1.** Tubular ducts with slender inner filament; **H2.** Tubular ducts with flowery tipped inner filament; **I1.** Microducts on dorsum; **I2.** Microduct with an expanded inner filament plus a long tail. **J1.** Anal plates (dorsal view); **J2.** Anal plates (ventral view, also showing ventral thickenings stippled); **K.** Anal ring; **L.** Submarginal seta; **M.** Ventral seta; **N.** Antenna; **O1.** Tibiotarsus of hind leg (showing tibiotarsal sclerotisation associated with free articulation); **O2.** Tibiotarsus of hind leg (showing tibiotarsal sclerotisation not associated with free articulation); **O3.** Tibiotarsus of hind leg (showing no tibiotarsal sclerotisation and no free articulation); **P.** Spiracles: 1. not surrounded by sclerotic plate, 2. surrounded by sclerotic plate; **Q.** Spiracular pores: 1. three loculi, 2. four loculi, 3. quiquelocular; **R1.** Multilocular pore, **R2.** Multilocular pore with slit in central loculus, **R3.** Multilocular pore with well developed central loculus and with a vertical projecting partition bearing a groove-like slit in the middle; **S1.** Tubular ducts with slender inner filament; **S2.** Tubular ducts with flowery tipped inner filament; **S3.** Short tubular duct with a very long flowery inner filament; **T.** microducts on venter

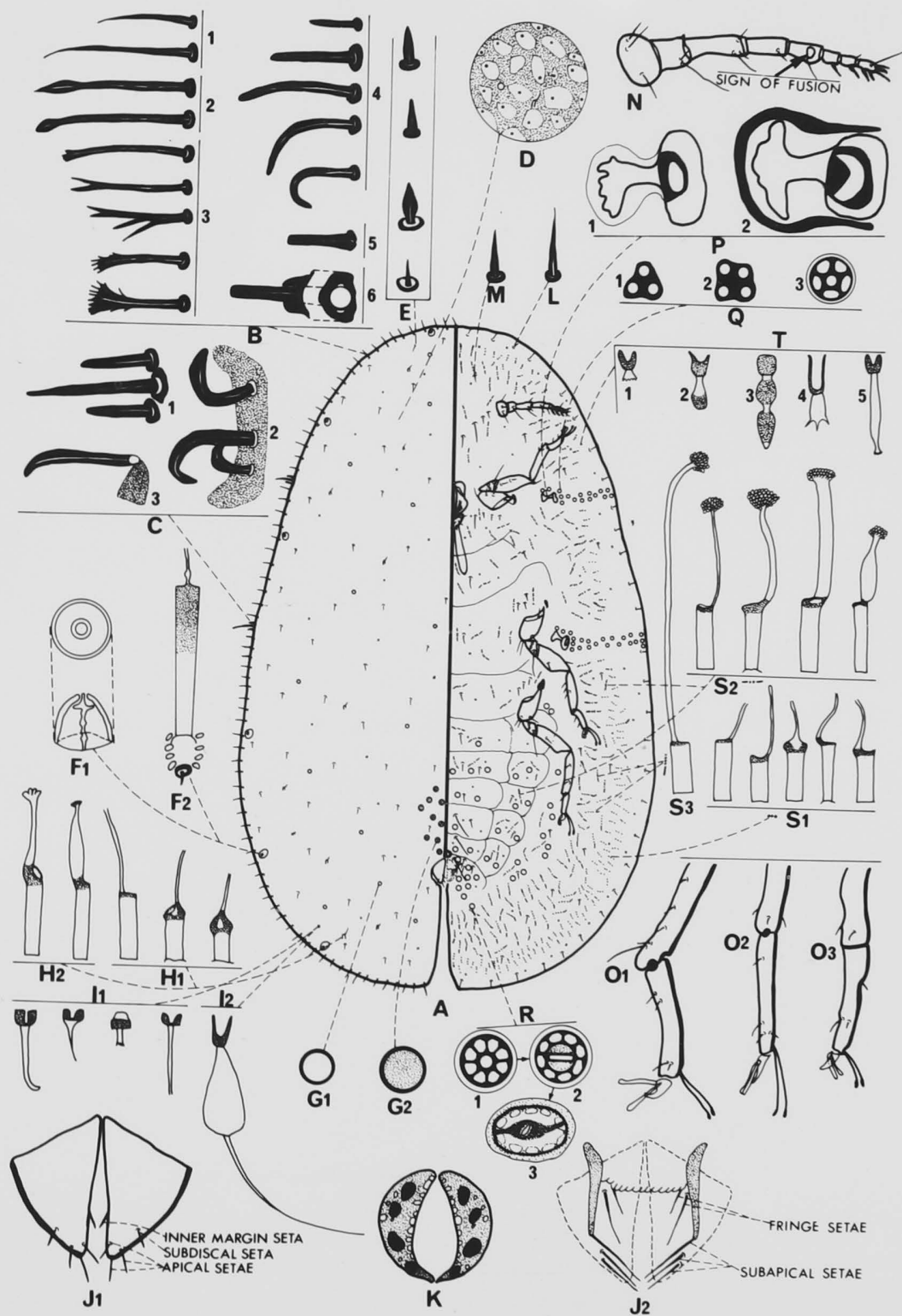
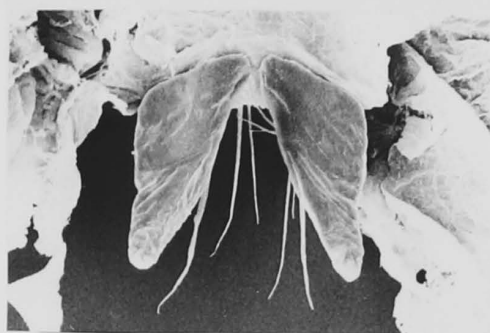
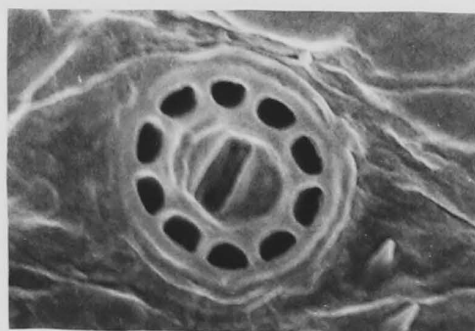


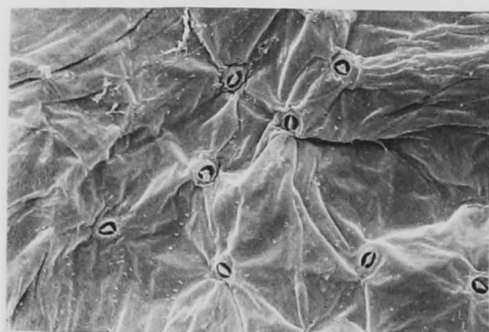
Fig. 2. Scanning electron micrographs. **A.** Anal plates of *P. dodonaeae*, scale line, 100 μm ; **B.** Multilocular pore of *P. dodonaeae* showing central locus with a slit, scale line, 2 μm ; **C.** Multilocular pore of *P. flavicans*, scale line, 25 μm ; **D.** Multilocular pores of *P. flavicans* showing the outer ring of loculi (arrowed) which cannot be seen under the light microscope, the expanded central locus, the vertical projecting partition with a groove-like slit in the middle, scale line, 2 μm ; **E.** Tubular duct with slender inner filament of *P. polygonata*, '++' marking the total length, scale line, 5 μm ; **F.** Tubular duct with flowery tipped inner filament of *P. polygonata*, '+-' marking the total length, scale line, 10 μm ; **G, H.** Microduct on venter of *P. flavicans* showing bulbous or dumb-bell shaped inner filament, '+-+' marking the total length, scale line, 2 μm .



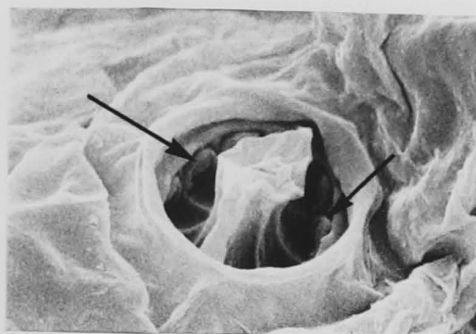
A



B



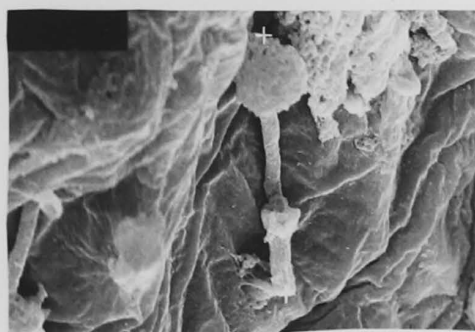
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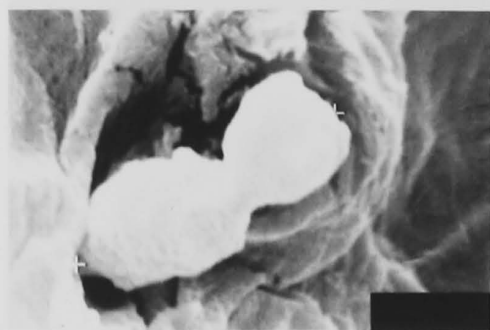
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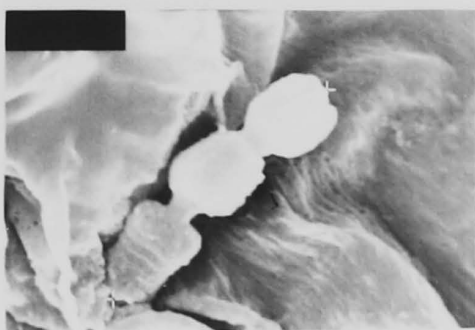
E



F



G



H

Fig. 3. Adult female of *P. decorata* Borchsenius. A. Body derm (dorsum on left, venter on right); B. Marginal setae; C. Spiracular setae; D. Cell-like clear areas; E. Dorsal seta; F. Submarginal tubercle; G. Discoidal pore; H. Tubular duct; I. Microduct; J1. Anal plates (dorsal view); J2. Anal plates (ventral view, also showing ventral thickenings stippled); L. Submarginal seta; M. Ventral seta; N. Antenna; O. Tibiotarsus of hind leg; P. Spiracles; Q. Spiracular pore; R. Multilocular pore; S1. Tubular ducts with slender inner filament; S2, S3. Tubular ducts with flowery tipped inner filament; T. Microduct on venter.

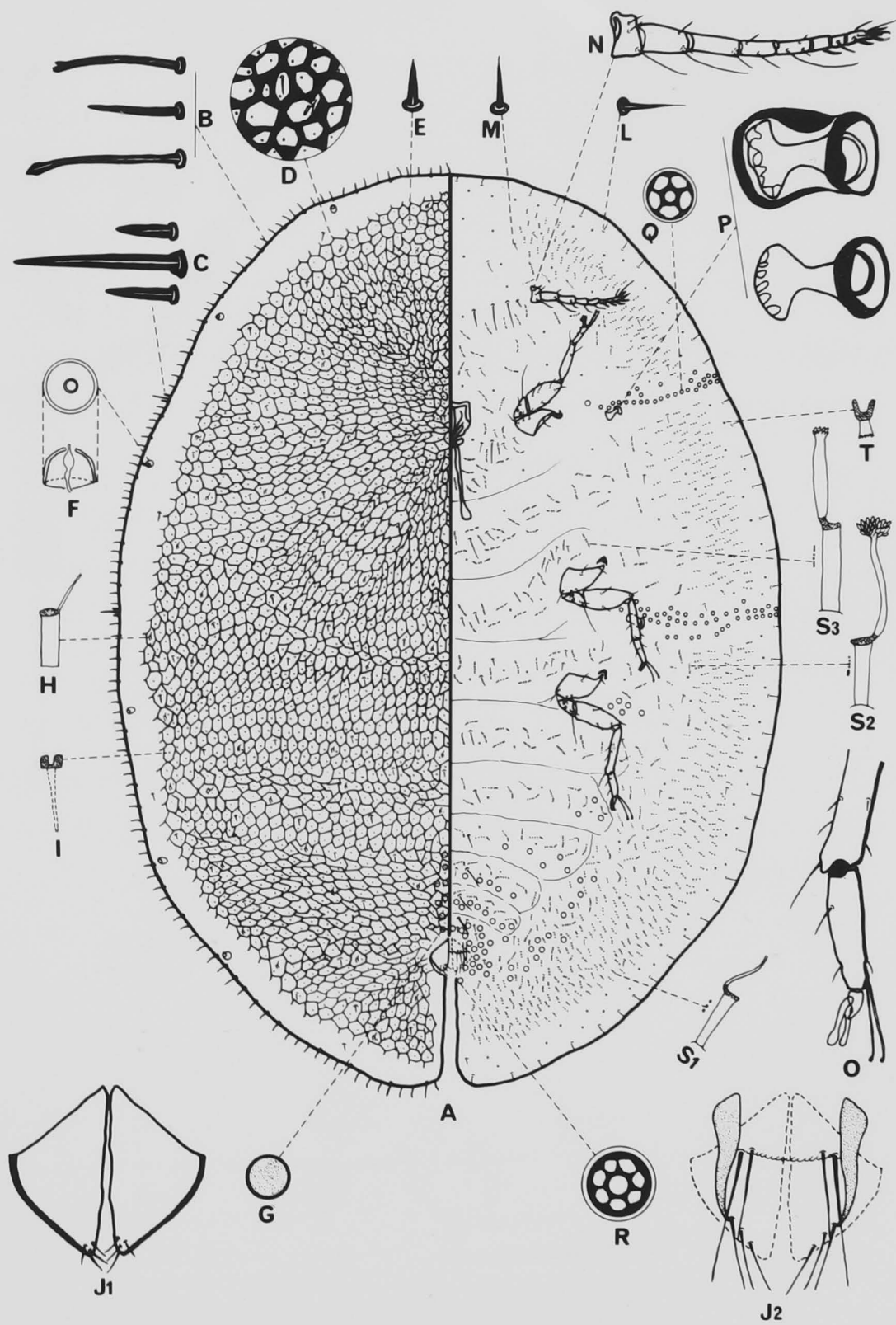


Fig. 4. Adult female of *P. dodonaeae* Maskell. **A.** Body derm (dorsum on left, venter on right); **B.** Marginal setae; **C.** Spiracular setae associated with spiracular sclerotisation; **E.** Dorsal seta; **F.** Submarginal chambered ducts; **G1.** Disc pore; **G2.** Discoidal pores in loose bands in the submedian area on each side of body from above the level of the antennal base to near the anal plates; **H.** Tubular duct; **I.** Microduct; **J1.** Anal plates (dorsal view); **J2.** Anal plates (ventral view, also showing ventral thickenings stippled); **K.** Anal ring; **L.** Submarginal seta; **M.** Ventral seta; **N.** Antenna; **O.** Tibiotarsus of hind leg (also showing claw denticle near apex); **P.** Spiracle; **Q.** Spiracular pore; **R.** Multilocular pore with a slit in central loculus; **S.** Tubular duct; **T.** Microduct on venter.

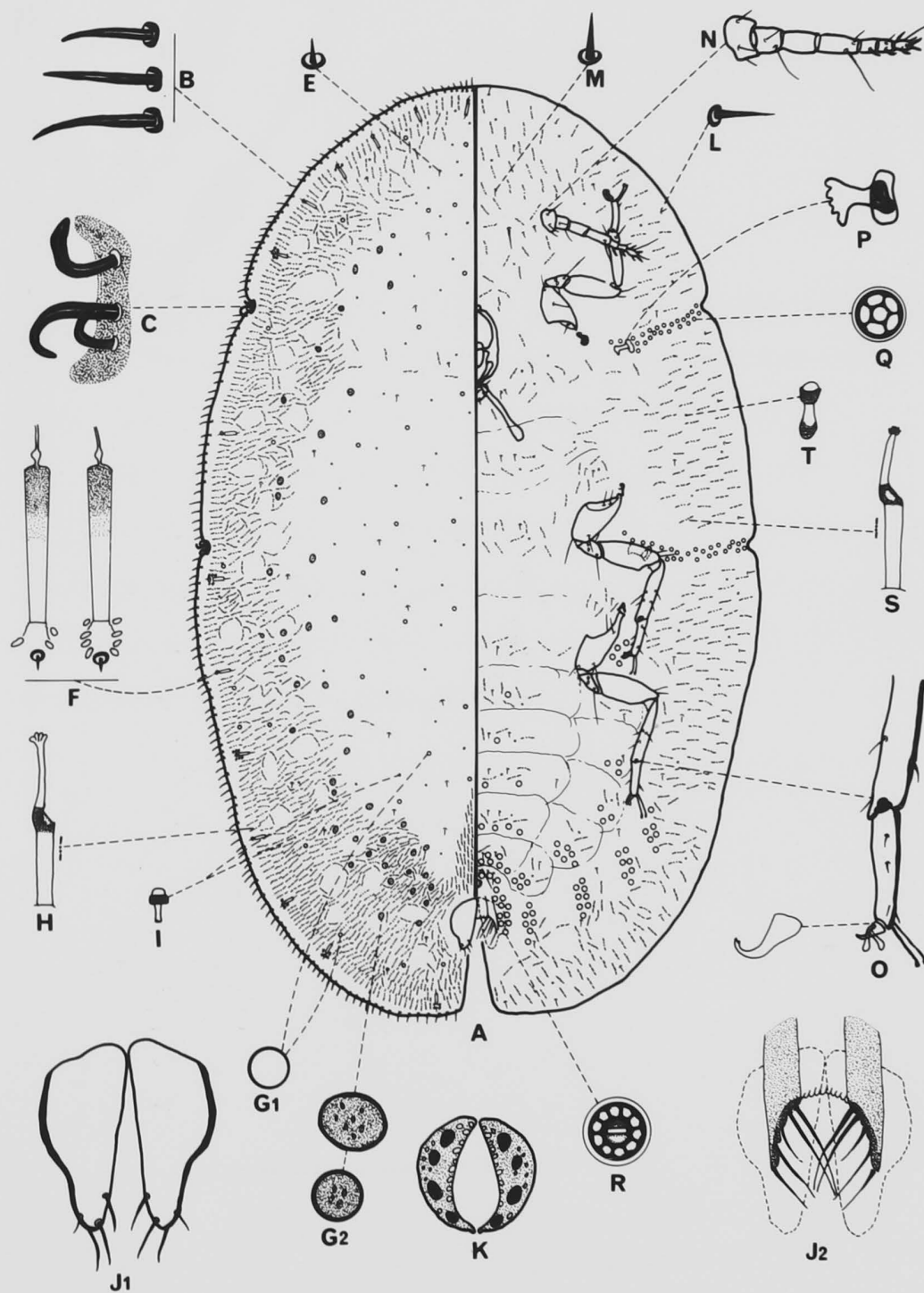


Fig. 5. Adult female of *P. elongata* Newstead. **A.** Body derm (dorsum on left, venter on right); **B.** Marginal setae; **C.** Spiracular setae; **E.** Dorsal seta; **G.** Discoidal pore; **H.** Tubular duct; **I.** Microduct; **J1.** Anal plates (dorsal view); **J2.** Anal plates (ventral view, also showing ventral thickenings stippled); **L.** Submarginal seta; **M.** Ventral seta; **N.** Antenna; **O.** Tibiotarsus of hind leg; **P.** Spiracle; **Q.** Spiracular pore; **R.** Multilocular pore; **S1.** Tubular duct with slender inner filament; **S2, S3.** Tubular ducts with flowery tipped inner filament; **T.** Microduct on venter.

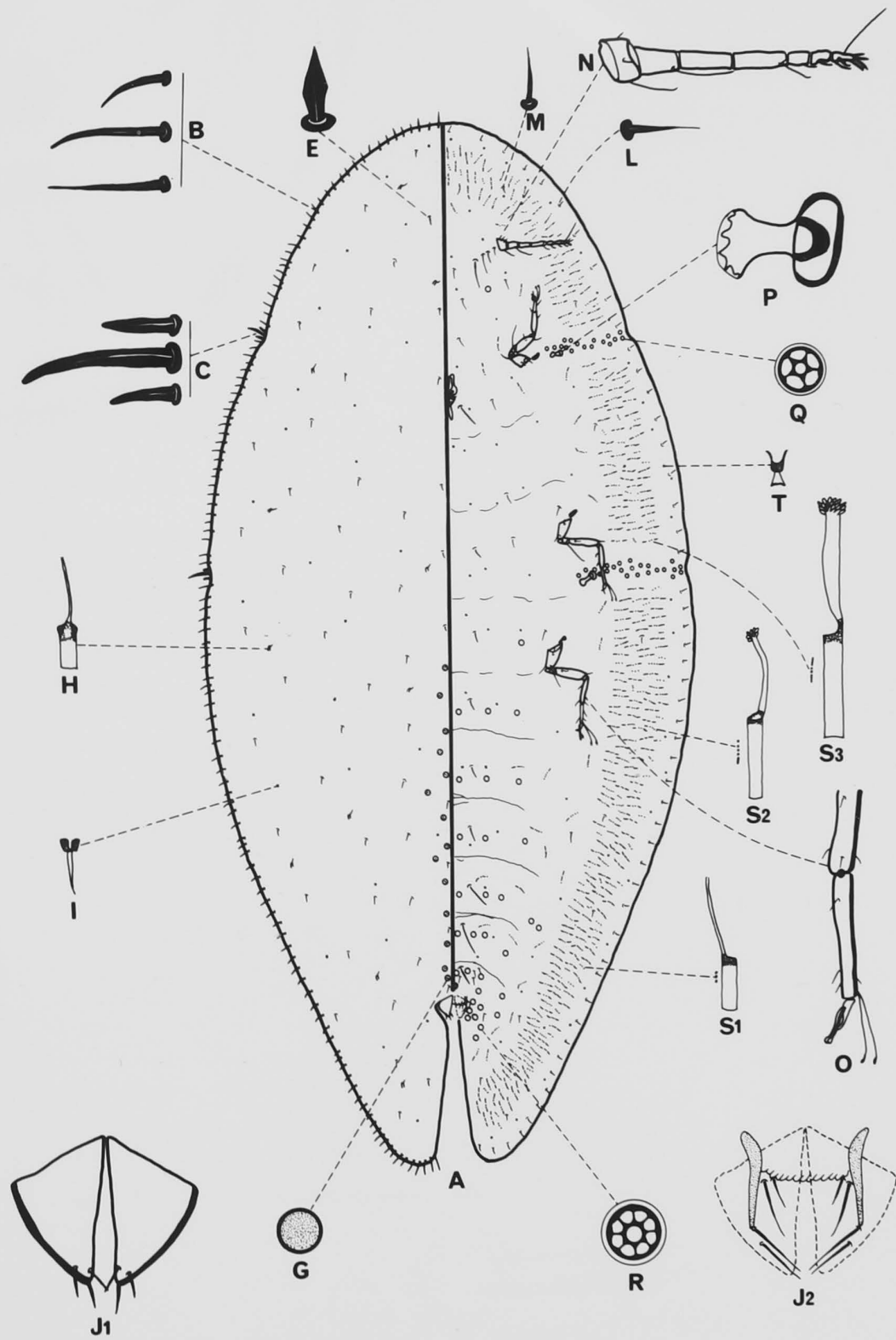


Fig. 6. Adult female of *P. flavicans* Maskell. A. Body derm (dorsum on left, venter on right); B. Marginal setae; C. Spiracular seta associated with spiracular sclerotisation; E. Dorsal seta; G. Disc pore; H. Tubular ducts; J1. Anal plates (dorsal view); J2. Anal plates (ventral view, also showing ventral thickenings stippled); K. Anal ring; L. Submarginal seta; M. Ventral seta; N. Antenna; O. Tibiotarsus of hind leg (also showing claw denticle near apex); P. Spiracle; Q. Spiracular pore; R. Multilocular pore; S. Tubular duct; T. Microduct on venter.

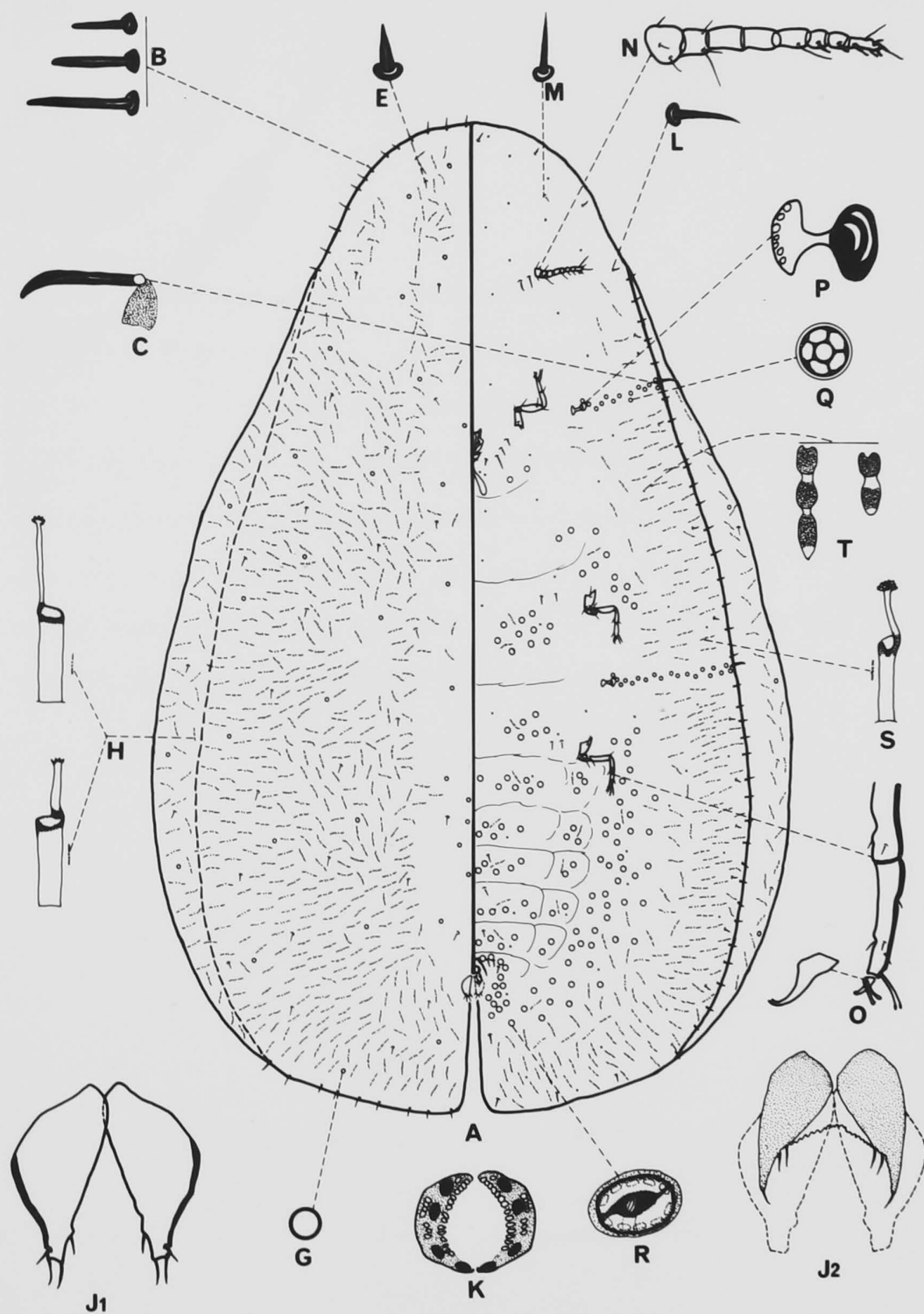


Fig. 7. Adult female of *P. floccifera* (Westwood). **A.** Body derm (dorsum on left, venter on right); **B.** Marginal setae; **C.** Spiracular setae; **E.** Dorsal seta; **F.** Submarginal tubercle; **G1.** Disc pore; **G2.** Discoidal pore; **H.** Tubular duct; **J1.** Anal plates (dorsal view); **J2.** Anal plates (ventral view, also showing ventral thickenings stippled); **L.** Submarginal seta; **M.** Ventral seta; **N.** Antenna; **O.** Tibiotarsus of hind leg; **P.** Spiracle; **Q.** Spiracular pore; **R.** Multilocular pore; **S1.** Tubular duct with slender inner filament; **S2, S3.** Tubular ducts with flowery tipped inner filament; **T.** Microduct on venter.

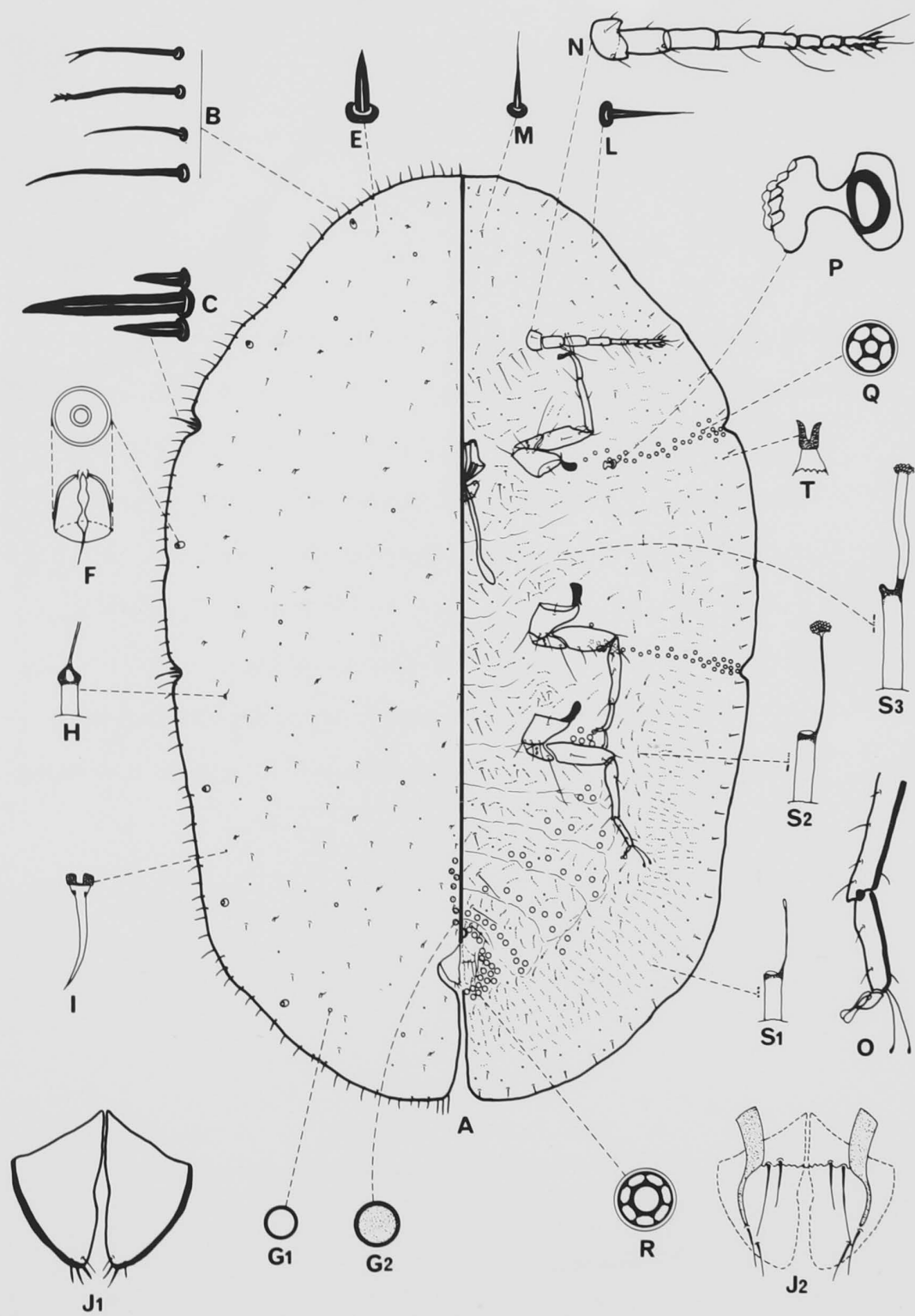


Fig. 8. Adult female of *P. hydrangeae* Steinweden. A. Body derm (dorsum on left, venter on right); B. Marginal setae; C. Spiracular setae; E. Dorsal seta; G. Discoidal pore; H. Tubular duct; I. Microduct; J1. Anal plates (dorsal view); J2. Anal plates (ventral view, also showing ventral thickenings stippled); L. Submarginal seta; M. Ventral seta; N. Antenna; O. Tibiotarsus of hind leg; P. Spiracle; Q. Spiracular pore; R. Multilocular pore; S1. Tubular duct with slender inner filament; S2, S3, S4. Ventral tubular ducts with flowery tipped inner filament (also showing different thicknesses of inner filaments); T. Microduct on venter.

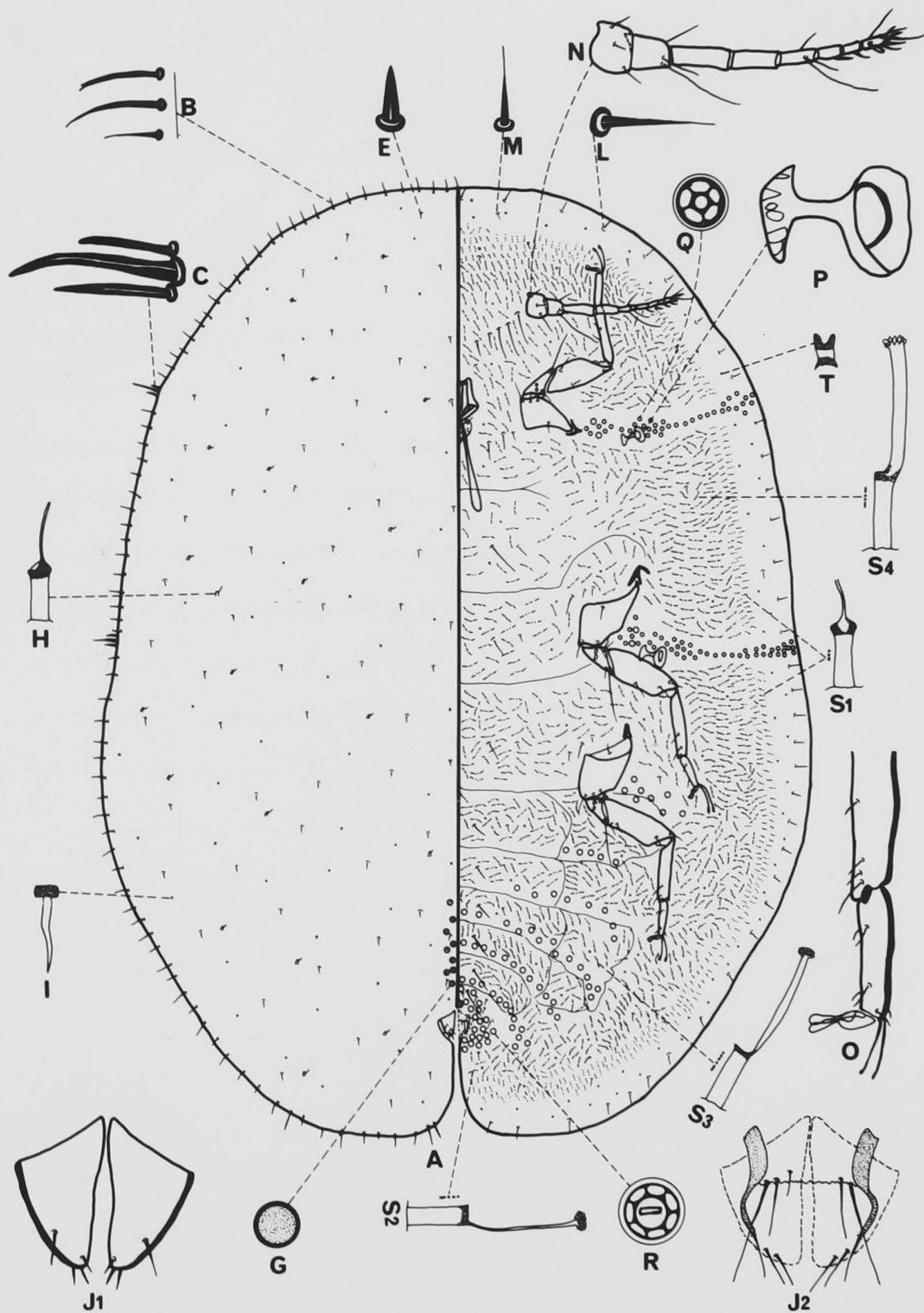


Fig. 9. Adult female of *P. maskelli* Maskell. A. Body derm (dorsum on left, venter on right); B1. Marginal setae; B2. Marginal seta with large base; C1, C2. Spiracular setae; E. Dorsal seta; G1. Disc pore; G2. Discoidal pore; I. Microduct; J1. Anal plates (dorsal view): (1) first inner margin seta at $1/2$ distance along inner margin, (2) first inner margin seta at $2/3$ distance along inner margin; J2. Anal plates (ventral view, also showing ventral thickenings stippled); K. Anal ring; L. Submarginal setae; M. Ventral seta; N. Antenna; O. Tibiotarsus of hind leg; P. Spiracle; Q. Spiracular pore; R. Multilocular pore; S1, S2. Tubular ducts; T. Microducts on venter.

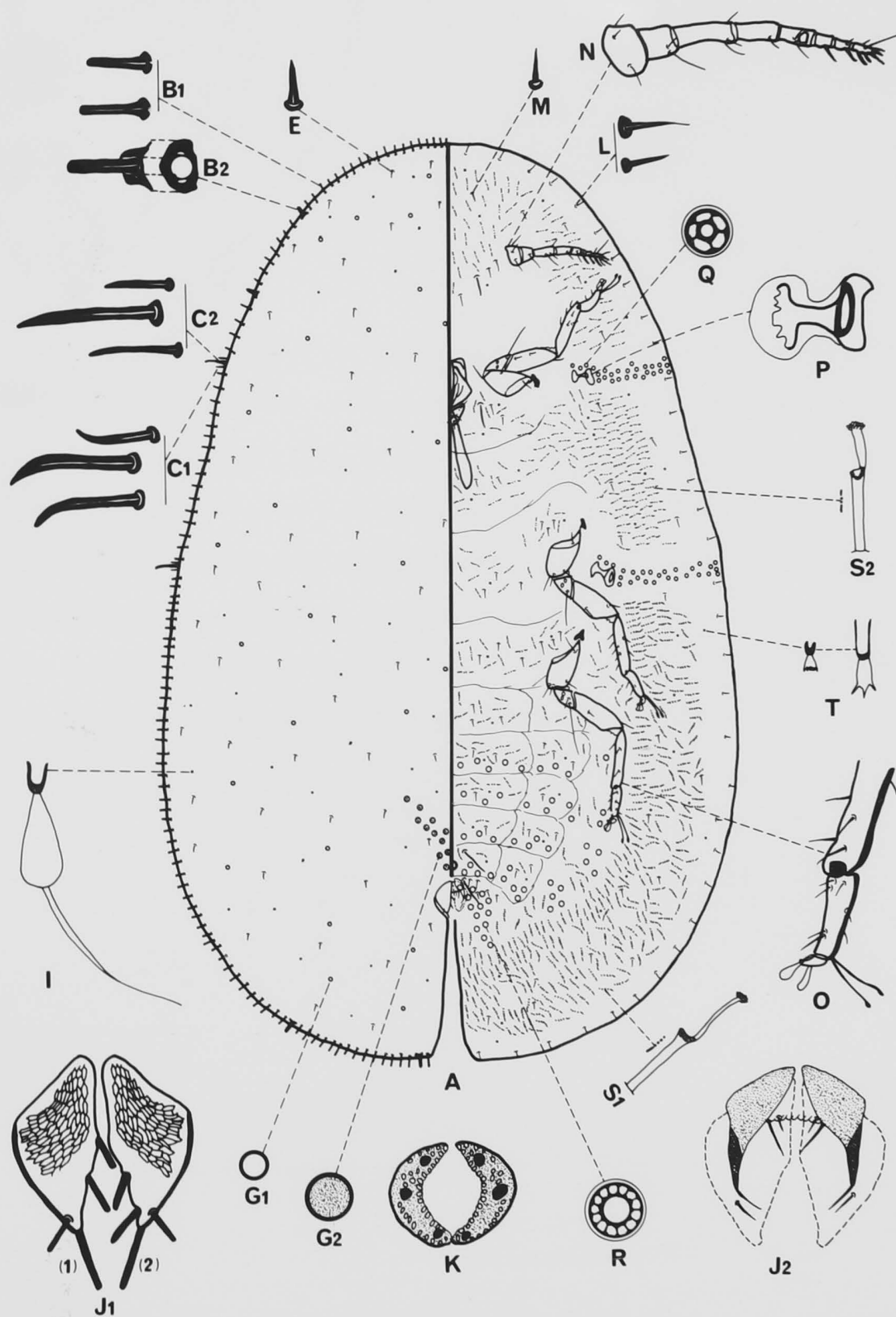


Fig. 10. Adult female of *P. mesembryanthemi* (Vallot). A. Body derm (dorsum on left, venter on right); B. Marginal setae; C. Spiracular setae; E. Dorsal seta; G. Discoidal pore; H. Tubular duct; I. Microduct; J1. Anal plates (dorsal view); J2. Anal plates (ventral view, also showing ventral thickenings stippled); L. Submarginal seta; M. Ventral seta; N. Antenna; O. Tibiotarsus of hind leg; P. Spiracle; Q. Spiracular pore; R. Multilocular pore; S1. Tubular duct with slender inner filament; S2, S3. Tubular ducts with flowery tipped inner filament; T. Microduct on venter.

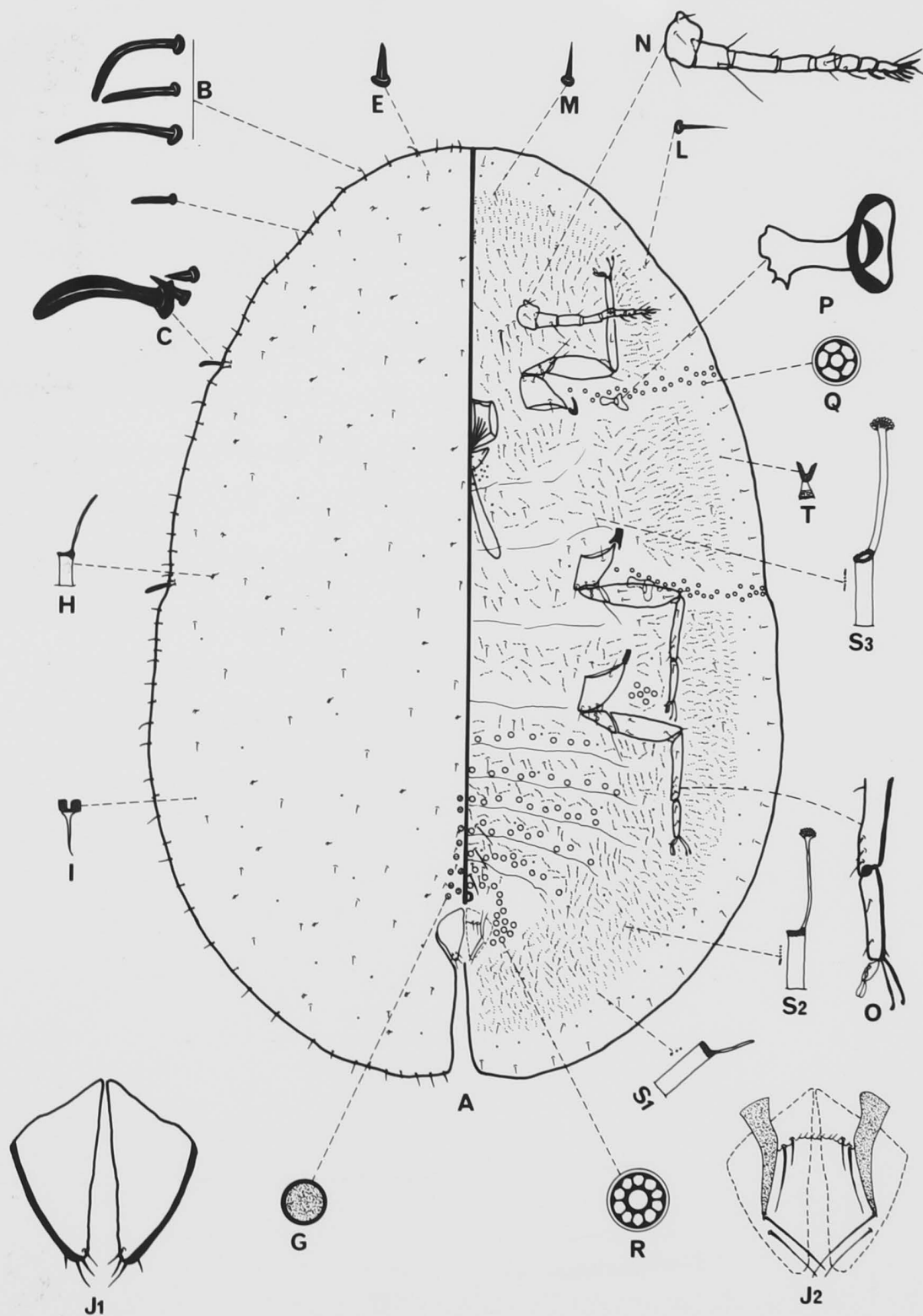


Fig. 11. Adult female of *P. polygonata* Cockerell. **A.** Body derm (dorsum on left, venter on right); **B.** Marginal setae; **C.** Spiracular setae; **D.** Cell-like clear areas; **E.** Dorsal seta; **F.** Submarginal tubercle; **G.** Discoidal pore; **H.** Tubular duct; **I.** Microduct; **J1.** Anal plates (dorsal view); **J2.** Anal plates (ventral view, also showing ventral thickenings stippled); **L.** Submarginal seta; **M.** Ventral seta; **N.** Antenna; **O.** Tibiotarsus of hind leg; **P.** Spiracle; **Q.** Spiracular pore; **R.** Multilocular pore; **S1.** Tubular duct with slender inner filament; **S2.** Tubular duct with flowery tipped inner filament; **T.** Microduct on venter.

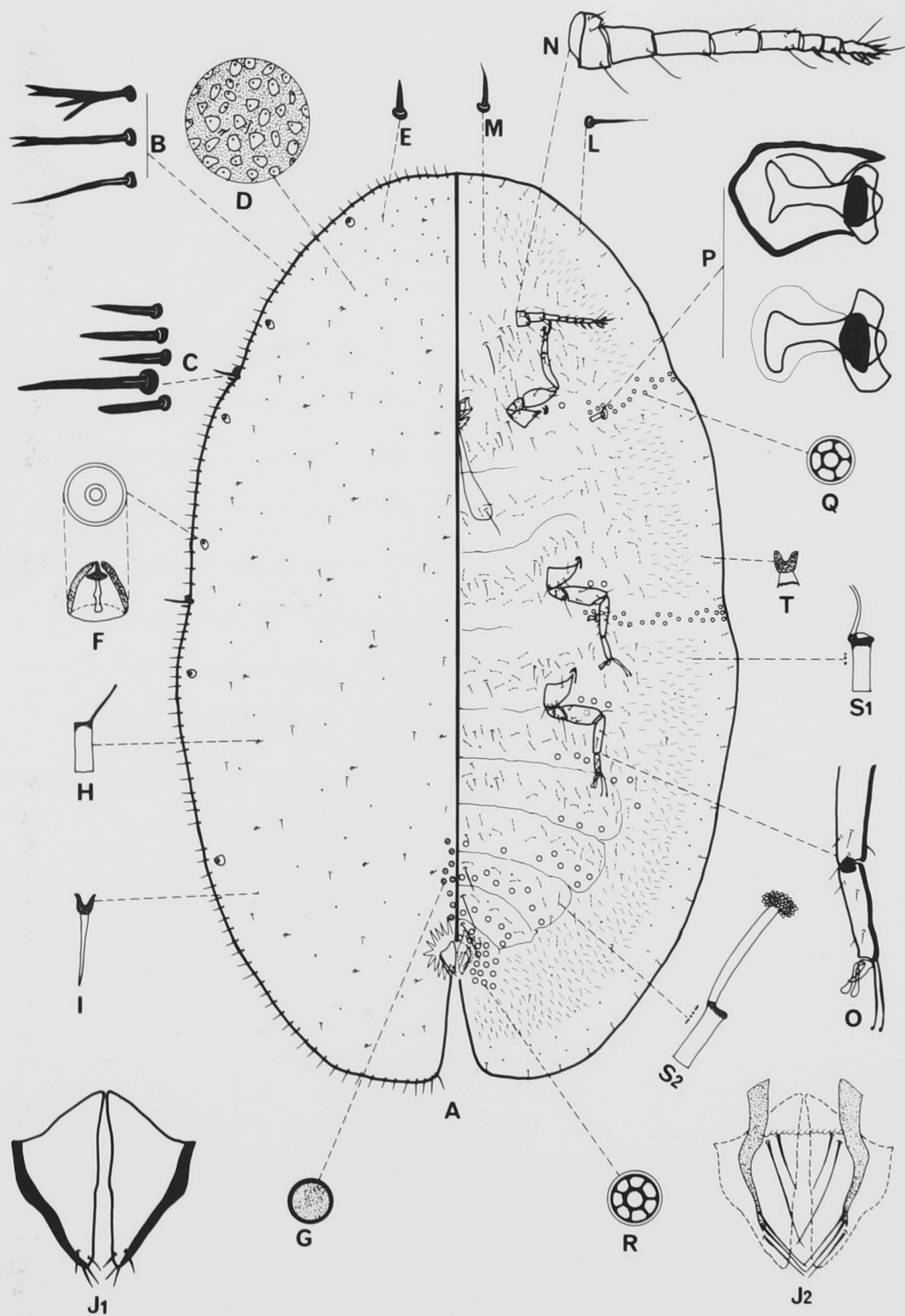


Fig. 12. Adult female of *P. psidii* Maskell. **A.** Body derm (dorsum on left, venter on right); **B.** Marginal setae; **C.** Spiracular setae; **D.** Cell-like clear areas; **E.** Dorsal seta; **F.** Submarginal tubercle; **G.** Discoidal pore; **H.** Tubular duct; **I.** Microduct; **J1.** Anal plates (dorsal view); **J2.** Anal plates (ventral view, also showing ventral thickenings stippled); **K.** Anal ring; **L.** Submarginal seta; **M.** Ventral seta; **N.** Antenna; **O.** Tibiotarsus of hind leg; **P.** Spiracle; **Q.** Spiracular pore; **R.** Multilocular pore; **S1.** Tubular duct with slender inner filament; **S2.** Tubular duct with flowery tipped inner filament; **S3.** Short duct with a very long flowery inner filament; **T.** Microduct on venter.

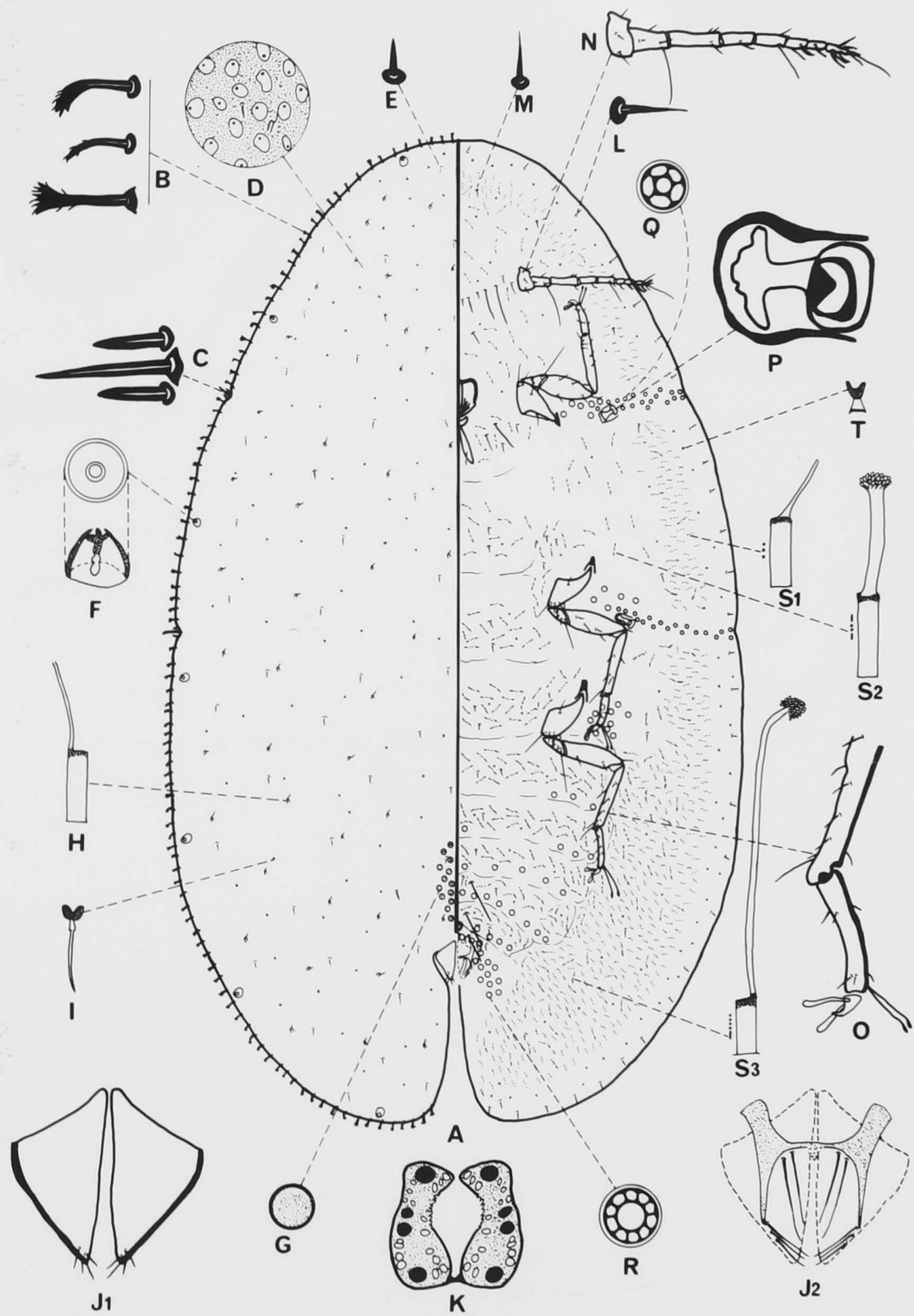


Fig. 13. Adult female of *P. salicorniae* Froggatt. A. Body derm (dorsum on left, venter on right); B. Marginal setae; E. Dorsal seta; G. Discoidal pores in loose bands in the submedian area on each side of body from above the level of the second coxa to near the anal plates; H. Tubular duct; I. Microduct; J1. Anal plates (dorsal view); J2. Anal plates (ventral view, also showing ventral thickenings stippled); K. Anal ring; L. Submarginal seta; M. Ventral seta; N. Antenna; O. Tibiotarsus of hind leg; P. Spiracle; Q. Spiracular pore; R. Multilocular pores; S. Tubular ducts; T. Microduct on venter.

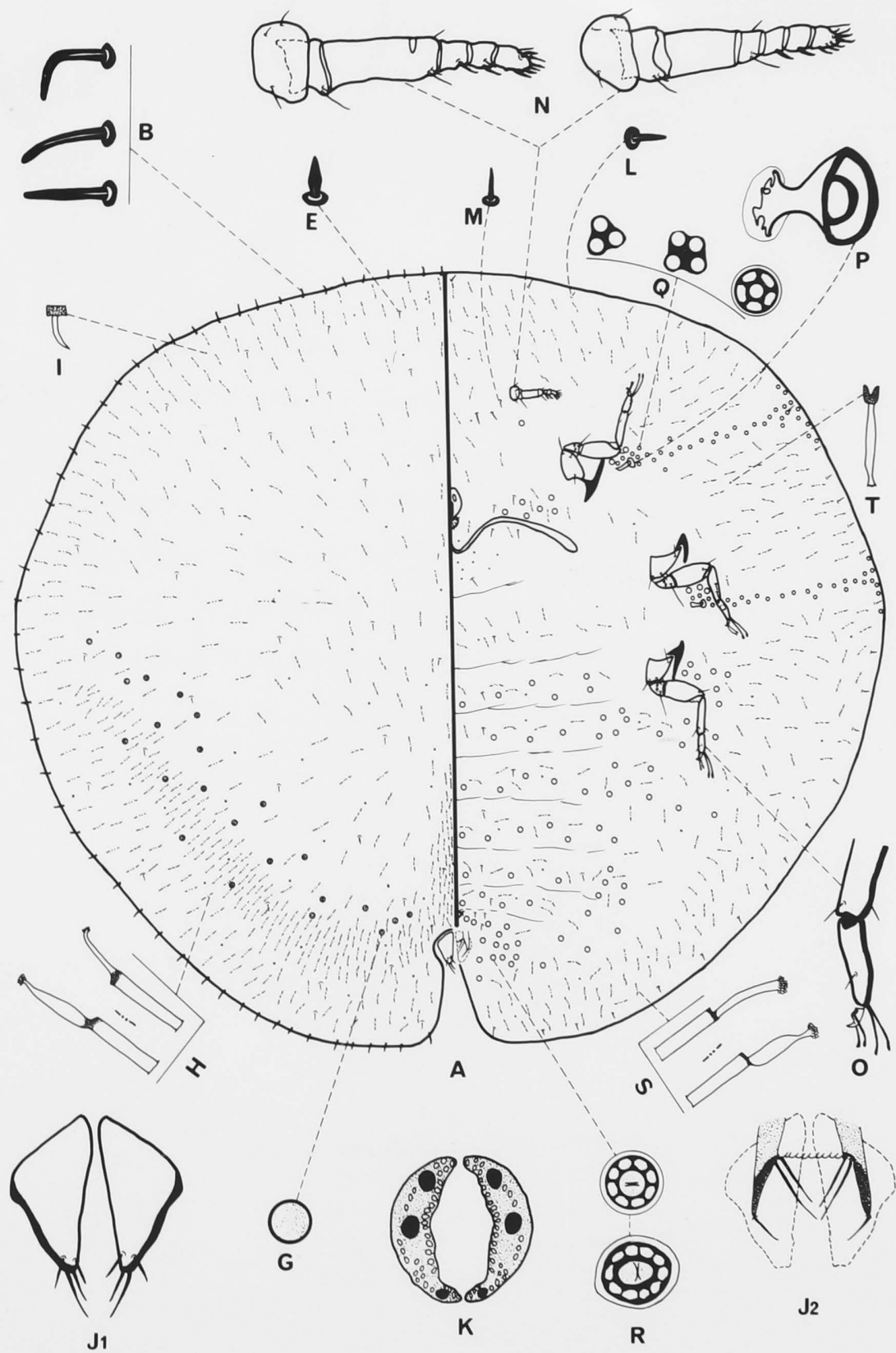


Fig. 14. Adult female of *P. thompsoni* Maskell. **A.** Body derm (dorsum on left, venter on right); **B.** Marginal setae; **C.** Spiracular setae associated with spiracular sclerotisation; **E.** Dorsal seta; **G1.** Disc pore; **G2.** Discoidal pores; **I.** Microduct; **J1.** Anal plates (dorsal view); **J2.** Anal plates (ventral view, also showing ventral thickenings stippled); **K.** Anal ring; **L.** Submarginal seta; **M.** Ventral seta; **N.** Antenna; **O.** Tibiotarsus of hind leg; **P.** Spiracle; **Q.** Spiracular pore; **R.** Multilocular pore; **S1, S2.** Tubular ducts; **T.** microduct on venter.

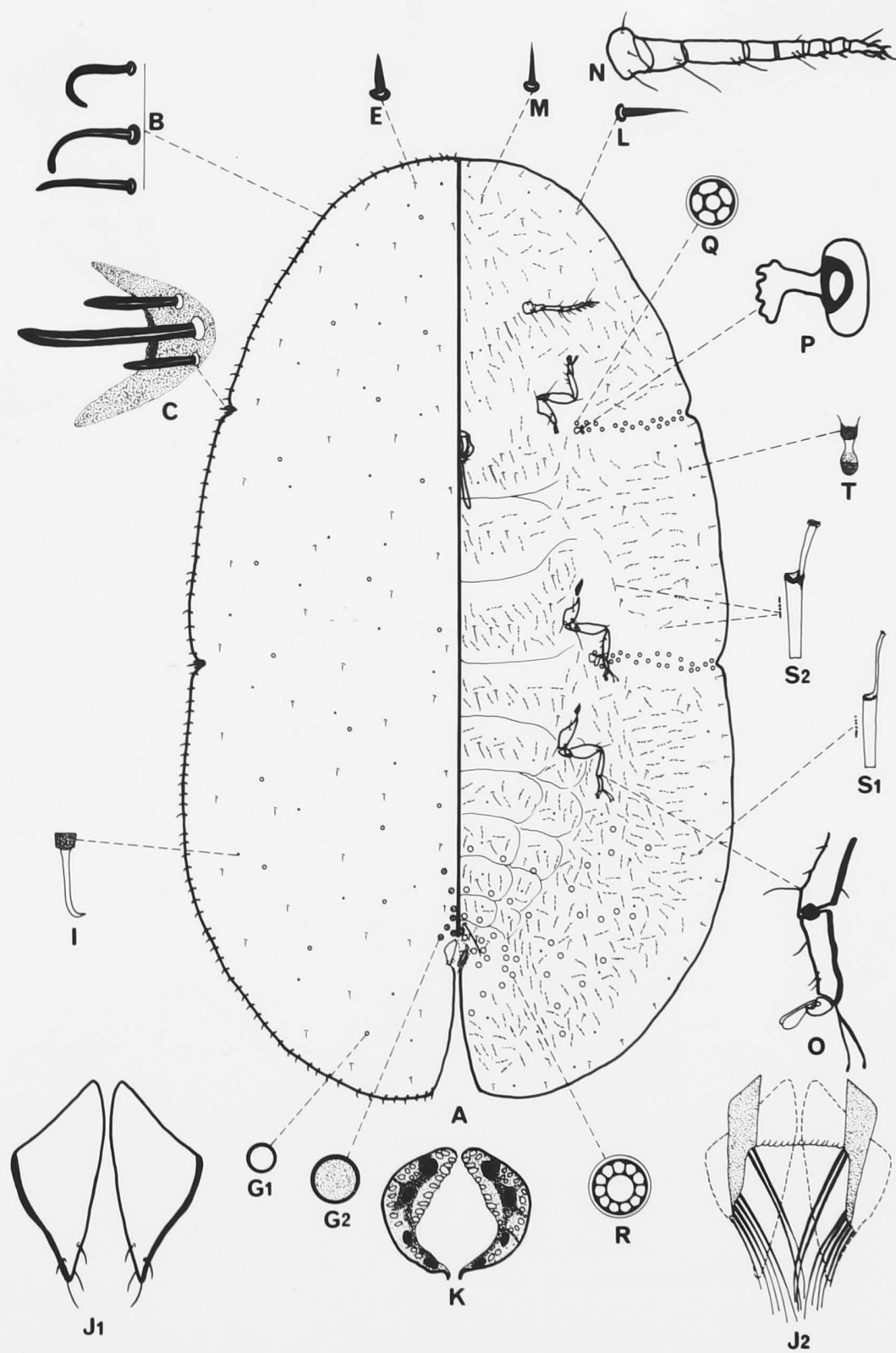


Fig. 15. Adult female of *P. sp. n.* A. Body derm (dorsum on left, venter on right); B. Marginal setae; C. Spiracular setae; E. Dorsal seta; G. Discoidal pore; H. Tubular duct; I. Microduct; J1. Anal plates (dorsal view); J2. Anal plates (ventral view, also showing ventral thickenings stippled); L. Submarginal seta; M. Ventral seta; N. Antenna; O. Tibiotarsus of hind leg; P. Spiracle; Q. Spiracular pore; R. Multilocular pore; S1. Tubular duct with slender inner filament; S2, S3. Tubular ducts with flowery tipped inner filament; T. Microduct on venter.

